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Development and Process Controls for Surimi Production

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Part II

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MARCH 1988

DEVELOPMENT OF PROCESS CONTROLS FOR SURIMI PRODUCTION

PART II

BY

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Note: Copies of appendices to this report are available from:

Fisheries Development Division
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Abstract

This report covers the second phase of a project to develop methods for producing surimi from cod frame waste materials and to develop equipment to facilitate automation of the process.

The investigation of processing methodologies has lead to the conclusions that the functional properties of surimi can be controlled through control of pH and water content. Hardness is directly influenced by surimi water content while elasticity is independently controlled by surimi pH. Unfortunately, pH also directly influences surimi water content in such a way that a processing pH resulting in a high elasticity results in a low rigidity and vice versa.

An apparently novel processing methodology has been specified for independent control of water content and pH. This methodology allows the production of cod frame surimi with functional properties that can be independently controlled by the processor according to market requirements.

The process monitoring system that was used during the investigation of processing methodologies was also a test bed for sensing hardware and process control methods. Real-time operator feedback of process conditions information was tried and proved to be a useful concept.

A hybrid process controller "OPERATING ASSISTANT" has been designed on the basis of the success of the sensors, processing methodologies and control concepts. The "OPERATING ASSISTANT" should enable any competent operator to produce good quality surimi from cod frame materials.

RÉSUMÉ

Le présent rapport porte sur la deuxiéme phase d'un project de développment de méthodes de production du surimi à partir de résidus provenant des carcasses de morue et de conception de matériel destiné a faciliter l'automatisation du procédé.

L'étude des méthodes de transformation a permis de conclure que l'on peut fixe les caractéristiques fonctionnelles du surimi par régulation de la teneur en eau et du pH de ce produit. La dureté dépend directement de cette teneur en eau, tandis qu'indépendamment de cette relation, l'élasticité est liée au pH du surimi. Malheureusement, le pH peut aussi influer directement sur la teneur en eau, de sorte que, dans le processus de transformation, un pH élevé donne une grande élasticité, mais aboutit aussi à une faible rigidité, et inversement.

Grâce à une méthode qui semble originale, on peut agir sur le contenu en eau et sur le pH, indépendamment l'un de l'autre, ce qui permet de prodoire, à partir de résidus de carcasses, du surimi dont les caractéristiques fonctionnelles peuvent être fixées séparément par le transformateur, selon les besoins du marché.

Le suivi du procédé utilisé dans le cadre de l'étude des methodes de transformation a également constitué un banc d'essai pour le matériel de rétro-information en temps réel sur les conditions de déroulement du procéde fournie par l'exploitant était un element utile.

On a conçu un régulateur de procédé hybride, désigné obtenus avec les capteurs, les méthodes de transformation et les concepts de regulation. Cet "ADJOINT A L'EXPLOITATION" devrait permettre à tout exploitant compétent de produire un surimi de bonne qualité à partir de résidus de carcasse de moruc.

1.0 INTRODUCTION

This is a report for the second and final phase of a project to develop a surimi process control system optimized for processing cod frame waste materials. The work was carried out by Canpolar Inc., in co-operation with the Newfoundland and Labrador Institute of Fisheries and Marine Technology (Marine Institute).

The project involved:

- the installation and evaluation of process sensors;
- the collection of processing data during pilot line operations;
- the evaluation of process information feedback to the operator;
- the development of a processing "recipe" for cod frame waste on the basis of processing experiments;
- the design of a process control system integrating all of the above findings.

The Marine Institute provided the processing facilities and managed the procurement of raw materials, surimi processing, storage and laboratory evaluation of surimi products. Canpolar was responsible for the design and installation of the sensor system, design of experimental protocols, process data collection, process interpretation and the design of the process control system.

The primary results from the two-year project have been:

1. Development of a processing methodology for preparation of functional surimi from cod frame wastes;
2. Development of the design for a semi-automated process control system based on evaluated hardware and methodologies.

1.1 Tasks

A real time display of process parameters was set up to provide the machine operator with immediate information. A display mounted above the existing control panel showed pH, temperature, salinity and screw press pressure in an easily readable format.

The primary activity was preparation of a display system packaged for in-plant operation and the preparation of software to generate displays.

DATA COLLECTION: The process monitoring system logged all process parameters as during the previous year's work (Canpolar, 1987). The existing sensors were refurbished and ion sensor manifold was redesigned for more reliable operation. Evaluation trials were made on additional sensors that might improve process monitoring. An inductive oceanographic salinometer was tried for ion monitoring. This sensor should provide maintenance free service as opposed to the electrode type ion sensors or conductivity meters. Methods for on-line moisture measurement were investigated.

QUALITY MEASUREMENT: Quality of cod raw materials including pH and color were evaluated. Quality measurement of kamaboko gels was an integral part of all of the experimental work and was an important factor in evaluating the effect of processing conditions.

A battery of standard tests was carried out on fresh and frozen products produced under varying operating conditions.

PROCESS MODELLING: The process model including physical/chemical parameters, machine operation and product quality and storage economics was developed and refined for cod frame waste. Completion of this task required a comprehensive set of process experiments similar to the pH experiment conducted during 1986/87.

Results from the 1986-87 surimi program suggested that final product texture could be controlled through utilization of processing conditions such as pH and ionic strength. (At lower moisture content surimi kamaboko products assume a harder texture). Reduction in the relative amount of functional myofibrillar protein results in reduced elasticity of the gel (i.e., the gel becomes brittle and the structure fails with little deformation). These findings are consistent with work done at North Carolina State University by Hamann and Lanier.

Process modelling was carried out in the context of desirable final product properties including kamaboko gel elasticity and yield points as determined by the torsion test of Lanier and Hann, 1985.

EQUIPMENT PREPARATION: The sensors on the pilot line were replaced, repaired or refurbished as required and the data logging system was reinstalled and tested.

An oceanographic type of inductive salinometer was tested as a substitution for the specific ion electrodes. The potential advantage is long term, trouble free operation.

Methods for on-line moisture measurement were investigated. If possible to accomplish, real time moisture determination is an important process control parameter.

A display monitor was installed on the pilot line to provide the

operator with real time process information from the data collection system.

EXPERIMENTAL WORK: The development of a useful process model that can be applied to either manual or automated control of surimi production required the completion of experiments that identify optimal processing conditions.

A series of experiments was designed to complete the process model. Twenty-five experimental runs were carried out at different operating conditions. Each "run" included:

1. Procurement and characterization of input materials for about 35-50 kg. batch;
2. operation of the pilot line as per a specified protocol;
3. preparation of surimi;
4. immediate analysis of kamaboko product;
5. storage (3 months, -18°C) of surimi product followed by a repeated analysis of kamaboko product.

Process data was logged automatically during all scheduled pilot line runs.

INTERPRETATION AND REPORTING: Interpretation of experimental results led to the development of a model of the surimi process that could be integrated into a process control algorithm.

This report includes: A complete appendix of process data; technical documentation of hardware and software; process interpretation, and a system design for a surimi process controller including hardware and software functional specifications.

2.0 TECHNOLOGY AND HARDWARE

The first objective to be accomplished at the start of this project was to upgrade the existing surimi pilot line data collection system to provide "real time" processing information. This included recalibration of the sensors that were already installed on the pilot line and subsequently using the data collected from these sensors to build a real time display. Further to the refurbishment of the data collection system, evaluation trials of an inductive oceanographic salinometer have been performed and methods for on line moisture analysis have been studied. The following is a detailed discussion of the technology and hardware configuration for the upgraded surimi data collection system:

2.1 Data Collection System/Sensor Redesign

2.1.1 Data Collection System

The redesign of the data collection system was based primarily on the following criteria:

1. provision for a "real time" display panel of process data; and,
2. housing of hardware to withstand the fish plant environment.

Previous experiments provided a base of hardware to establish a "real time" display. A Hewlett Packard (HP) 3421A DAta Acquisition Unit was initially used to do the actual data collection and was interfaced to a HP 110 personal computer for the first three surimi runs of this project. During this period, the hardware and software was being configured to enable real time display of data.

Figure 2.1 is a schematic representation of the hardware installed on the surimi pilot line to achieve this real time display. The hardware includes:

- PC XT compatible computer, complete with a dual mode Compaq graphics card and monitor;
- Micro 488 General Purpose Interface Bus (GPIB);
- 75 OHM RF Modulator;
- .35m (14 in.) monitor mounted in watertight housing;
- 1m (3.81 ft.) Hewlett Packard Interface Bus (HPIB);
- 30m (100 ft.) Inmac shielded RS 232 cable;
- 30m (100 ft.) 75 ohm coaxial cable;
- 1m (3.81 ft.) RCA video jack;

Previous experience (Canpolar Inc., 1987) indicated that the computer should be protected from the wet, corrosive environment of the plant floor (thus the need for the equipment layout as shown in Figure 2.1). By running the necessary cables through the plant ceiling, the computer could be located 30m (100 ft.) away in an adjoining office.

The display monitor itself was mounted in a watertight box which was constructed of aluminum and plexiglass. The display was mounted between the two wash tanks to enable the operator to view the process from either end of the surimi line. Figure 2.2 shows the location of the display unit in relation to the surimi line. Process monitoring using this newly configured display control panel began with surimi run number four. From runs four through 12, data was collected from the various sensors and displayed in "real time" in tabular form, as shown in Appendix A, on the display panel. During this period, the software necessary to provide a more enhanced process monitoring display was being written.

2.1.1 Sensors

Specific ion electrodes for measuring the activity of sodium, calcium and potassium from previous experimental work, were found to be useful indicators of the surimi leaching kinetics during processing. However, the use of these electrodes in an industrial setting can be difficult. The specific ion electrodes were previously mounted in a stainless steel sampling system which was mounted remote from the surimi line. Samples of process fluid were continuously drawn off for measurement, using a vacuum pump. The stainless steel electrode manifold was configured in such a way that the specific ion electrodes were mounted horizontally. With this configuration, tiny air bubbles would form at the electrode membrane surface and cause erratic measurements. It was decided from the outset of this project that it would be useful to continue to use the specific ion electrodes since they previously provided important information. Based on this, a new electrode manifold was designed (Figure 2.4), that would mount the electrodes in a vertical, stable position. The pH electrode mounting was not changed until later in the project, since the data from this sensor had been consistent and reliable. The new specific ion electrode manifold was constructed of 316 stainless steel 3/8" npt tube fittings.

Data was collected for the first 12 surimi runs using this arrangement, but due to inconsistent and unreliable readings it was decided that continuing to monitor sodium, calcium and potassium concentration using specific ion electrodes was futile. As a result, the sensors were removed from the process line and the essential pH monitoring electrode was relocated as described in Figure 2.5.

During the course of last year's surimi project (Canpolar, 1987), the pressure transducer mounted on the screw press was accidentally broken during routine cleaning operations. This sensor was replaced with a new Senso-Metrics Incorporated Sp 91 KFS pressure transducer with a range of 0-700 kPa (0-100 psi). For calibration information refer to Appendix D.

2.2 Display Panel

An example of the "real time" display panel output is shown graphically in Figure 2.3. Process monitoring information includes temperature (°C) data from both wash tanks, rotary sieves one and two, the refiner and the screw press. Pressure (psi) is also monitored in the screw press. The pH of the process fluid in both wash tanks is also displayed. The temperature data in both wash tanks is readily displayed and is helpful to the operator when icing down the wash tanks to obtain 0°C (32°F).

The operation of the display systems begins by turning on the computer, the data logging unit (HP3421A), the display monitor, the pH electrode buffer, and the pressure transducer power supply. As well, a toggle switch located on the panel of the data logger must be set to the "Data Collection Off" position. When the computer is turned on, the display program automatically kicks in and the operator is instructed to type in information according to various prompts from the computer. These prompts include surimi experimental run number, mince type, ect. At this point the computer begins to monitor the individual sensors mounted on the surimi line and the information is displayed on the panel within the operator's view. Actual data collection begins the instant the mince is dumped into wash tank number one. The operator must set the toggle switch on the data logger to "Data Collection On" in order to indicate to the

computer that the process has begun. The data is stored (refer to Appendix A for raw data) and displayed throughout the entire process until the temperature in the screw press drops below 5°C (40°F). At this point in the surimi process, ice has been added to the screw press to act as a plug which pushes any accumulated surimi out of the screw press. When the pilot run is complete the operator resets the data logger toggle switch to "Data Collection Off" and turns off the power to the computer and peripherals. Meanwhile, the pilot run data is transferred to diskette and returned to the main office for same day interpretation.

The software used to create the display program was written using Microsoft Quick Basic Compiler. The program for the tabular and graphic display is given in Appendix C.

2.3 PH Monitoring

For the first 12 pilot line runs of this project one Canlab polymer body with a sealed reference combination electrode was used to monitor the pH of both wash tanks on the surimi pilot line. The pH electrode was mounted in a stainless steel manifold system and samples of fluid were siphoned off for measurement using a vacuum pump. This arrangement had previously provided excellent results and the same was true for the first 12 pilot runs of this project. Integral to the successful operation of this design was the excellent cleaning of the pH electrode during back flushing operations. At the end of a pilot run, the manifold housing the pH electrode was back flushed with clean water flowing at 70-100 kPa (10-15 psi). Visual inspection after back flushing indicated that there were no visible signs of particles fouling the electrode membrane surface. The only problem that was experienced with one pH electrode mounted

remotely from the pilot line was that the operator had to spend time manually switching valves during the course of the pilot run.

During the first 10 minutes of the run, samples of fluid would be drawn from wash tank number one. After the mince was pumped into wash tank number two, the operator would have to scurry to the vacuum control panel and manually switch valves to enable pumping of fluid from wash tank number two.

When the specific ion electrodes were removed from the sampling system, for lack of reliable measurements, it was decided to move the pH electrode from the remote sampling system for direct immersion in wash tank one. As well, a second pH electrode had to be added to the pilot line in wash tank number two. It was our opinion that we might simplify the process measurement system if we removed the vacuum system and thus reduce the amount of time that the operator would have to spend away from the actual process. A schematic representation of the pH electrode wash tank mounting system is shown in Figure 2.5. The electrode was mounted inside a 25 mm (1 in.) O.D. 316 SS tube that was approximately 600 mm (24 in.) in length. The tip of the pH electrode protruded from the bottom of the tubing, which was immersed in the process fluid. Process fluid was kept from entering inside the tubing by sealing the end of the tube and electrode within an "O" ring inside a 3/8" NPT male compression fitting. The electrode cable running along the inside of the tubing was interfaced to the data collection system located remote from the pilot line. Also, for cleaning purposes, a 1/8" O.D. water spray line was attached to the electrode mount to enable cleaning at the end of the run, without having to actually remove the electrode from its housing.

For the runs numbered 13, 14 and 15 the pH measurement provided consistent reliable data (refer to Appendix A for raw data). Previous calibration of the electrodes had shown that the electrodes were accurate within ± .05 pH units against standard buffers of pH 4.0 and 7.0.

During run 16, it was noticed that titrating the pH from 7.0 down to 6.0 required significant additions of acid. It was thought that this might be due to the specific characteristics of the material that was being processed. However, during run 17,the pH electrode measurements were not indicative of what we were used to reading (pH values of 0.02 and 0.0 for wash tank number one and two respectively). Immediately, we switched to manual data collection to monitor the pH, using a portable meter. In this way the experiment, from a control point of view, was not lost.

Prior to beginning any subsequent pilot runs, we began investigating reasons for the pH electrode malfunctioning. This required dismantling the electrodes and bringing them back to the lab. After removing the electrodes, we immediately determined that a significant build up of process material from previous experiments had accumulated on the surface of the pH electrode between the membrane and the housing. It was obvious at this point that the pH electrodes were not malfunctioning but were in fact making readings of the product that was baked on to the membrane surface, perhaps for two to three weeks. Apparently the spray line that was designed to clean the electrodes was, in fact, adding to the problem. By referring to Figure 2.5 one can see that the spray nozzle is directed vertically so that the water when it strikes the electrode forces any accumulated material between the electrode housing and the membrane. The electrodes were reinstalled on the pilot line for the balance of the

project, but the portable pH meter was used also as a backup to ensure reliable readings.

2.4 Oceanographic Salinometer

As noted previously in this report, the use of specific ion electrodes to monitor salt content in a process plant environment is very unreliable. The specific ion electrodes required continuous maintenance and still were unable to provide consistent, reliable data.

The use of an inductive oceanographic salinometer provides a gross measurement of the ionic strength in the process but it does so on a consistent, reliable maintenance-free basis.

The sensor used for evaluation (shown in Figure 2.6), is an Aanderaa Instruments Salinity Sensor model 2975, used with sensor read out unit 3012.

The salinity sensor consists of an 6061-T6 aluminum tube body measuring approximately 180mm x 50 mm (7.5 in x 6.6 in). The sensor output is 10 bit digital information, with output from the read-out unit programmable for asynchronous communications (RS-232). The display unit is also housed in a watertight 6061-T6 aluminum housing. The display output is in units of parts per thousand (ppt) and the range is 0-40 ppt. For further technical information refer to Appendix D.

The salinity sensor was mounted in wash tank number two and the display unit was mounted just above the wash tank for easy access by the operator. It would have been desirable to interface the sensor output directly to the surimi process display panel but it was decided that, due to the unconventional format of this sensor output (10 bit digital) trying to achieve this objective would be costly not only in terms of

hardware but manpower. However, the display unit that was provided with the salinometer performed very well as a process controller. The technical documentation in Appendix D indicates that the salinometer should be cleaned and checked regularly to avoid marine fouling. The salinometer, which was installed on the surimi pilot line from November 1, 1987, to March 11, 1988, provided consistent reliable data with a minimal amount of cleaning. The salinometer was cleaned together with the rest of the pilot line after each run. The sensor was never removed from the pilot line for repairs or intense cleaning.

2.5 Infrared Moisture Sensor

One of the objectives of this project was to evaluate methods for on-line moisture measurement. Infrared sensors have been successfully used in other food industries for moisture analysis (Williams & Norris, 1987). Infrared (IR) moisture sensors range in price from $8000.00 - $20,000.00 U.S. and due to budget limitations, we were prevented from purchasing one of these sensors for evaluation. However, we were able to contact a couple of IR moisture sensor manufacturers and they were willing to evaluate the performance of their IR sensors using frozen surimi samples which we sent to them.

Infrared Engineering of Waltham, Ma. markets an IR moisture sensor, model SM4, that has a range up to 90% ± 0.1% moisture depending upon material.

The physical characteristics of the material is an important criteria which influences the behaviour of Infrared Engineering's design. Their sales engineer, prior to making any measurements, indicated that if the surimi material exhibited a translucent (surface wetness) appearance

then it was likely that this sensor might not provide accurate data. In fact, as it turned out, the SM4 moisture sensor was unable to detect to any degree of accuracy the moisture content of any of the samples that were provided. Tests done by Infrared Engineering conclude that the translucency of samples sent resulted in significant reflectance of source light and hence no accurate measurement.

An article published by the Alaska Fisheries Development Foundation (Surimi Its American Now) makes reference to the fact that on-line moisture analysis is being used for surimi processing in Alaska using a Quadra Beam IR Moisture Analyzer. Based on this information we contacted Moisture Systems Corp. in Hopkinton, Ma. who market the Quadra Beam II Model 475 IR moisture analyzer. They informed us that they are involved in on-line moisture analysis of surimi in Alaska and were more than willing to evaluate our product. Eight samples were sent to Moisture Systems Corp, five of which were clearly marked with known moisture content. The Quadra Beam II Model 475 IR Moisture Analyzer uses a linear regression technique for calibration (refer to Appendix D for technical information on this sensor). It was our intent that five samples of known moisture would be used for the calibration and subsequently the remaining three samples could be evaluated for moisture content using the calibrated instrument. After performing the necessary tests, Moisture Systems Corp informed us that they were, like Infrared Engineering, having difficulties making measurements simply due to the nature of the product being measured. However, they did inform us that laboratory measurements vary widely with on-line measurements made on surimi in Alaska. An independent consultant, Dan Hawkins of Ameron Associates, who installed and maintains the Quadra Beam II Moisture Analyzer in Alaska,

informed us that installation of the Moisture Systems Sensor on-line required additional hardware in order to compensate for the physical translucency of the surimi material.

The miscellaneous hardware installed with the Quadra Beam II sensor includes a PVC pipe section mounted between the screw press and the moisture analyzer. This sealed pipe must be purged of dust particles and the air within the pipe between the sensor and the product must be dry. As well, the signal must be digitally integrated in order to provide an average reading due to the irregularity of the surimi surface.

According to the independent consultant in Alaska, accurate and reliable moisture measurements are being made on surimi using Moisture Systems Corp Quadra Beam II Model 475 IR moisture analyzer. Provided the necessary steps are taken to install the sensor properly, the moisture system can become a useful sensor in on-line moisture measurement as in Alaska.

It should be noted that Alaskan surimi is made from pollock and therefore its surface characteristics may be different than that of surimi made from cod fish. Installation of a Quadra Beam II IR sensor may work for cod-based surimi but there will undoubtedly be an initial break-in period.

2.6 Temperature and Pressure Measurement

The sensors used throughout this project have been evaluated mainly for integration into a surimi process control system. Accurate and reliable temperature and pressure measurements have been made on the surimi pilot line over the course of two years (Canpolar, 1987). Omega J type thermocouples required no maintenance or cleaning while the Senso

Metrics pressure transducer mounted on the screw press was cleaned periodically. "Real time" temperature measurements on the two wash tanks were useful from a processing view in that the operator instantly knew exactly what the temperature was and indicated when ice should be added to bring the temperature to 0°C (32°F). These wash tank thermocouples provided the necessary information to enable the wash temperature to be crudely controlled. Temperature measurements in the two rotary sieves, the refiner and the screw press were good indicators but practically it would have been difficult to control the temperature in these locations.

The Senso Metric pressure transducer did occasionally drift in terms of calibration but for the most part it was reliable. In terms of acting as a sensor to control the process, the pressure transducer did indicate to the operator when the product in the enclosed screw press was moving or stopped. Based on these readings, the operator would take appropriate steps to try and optimize the screw press operation.

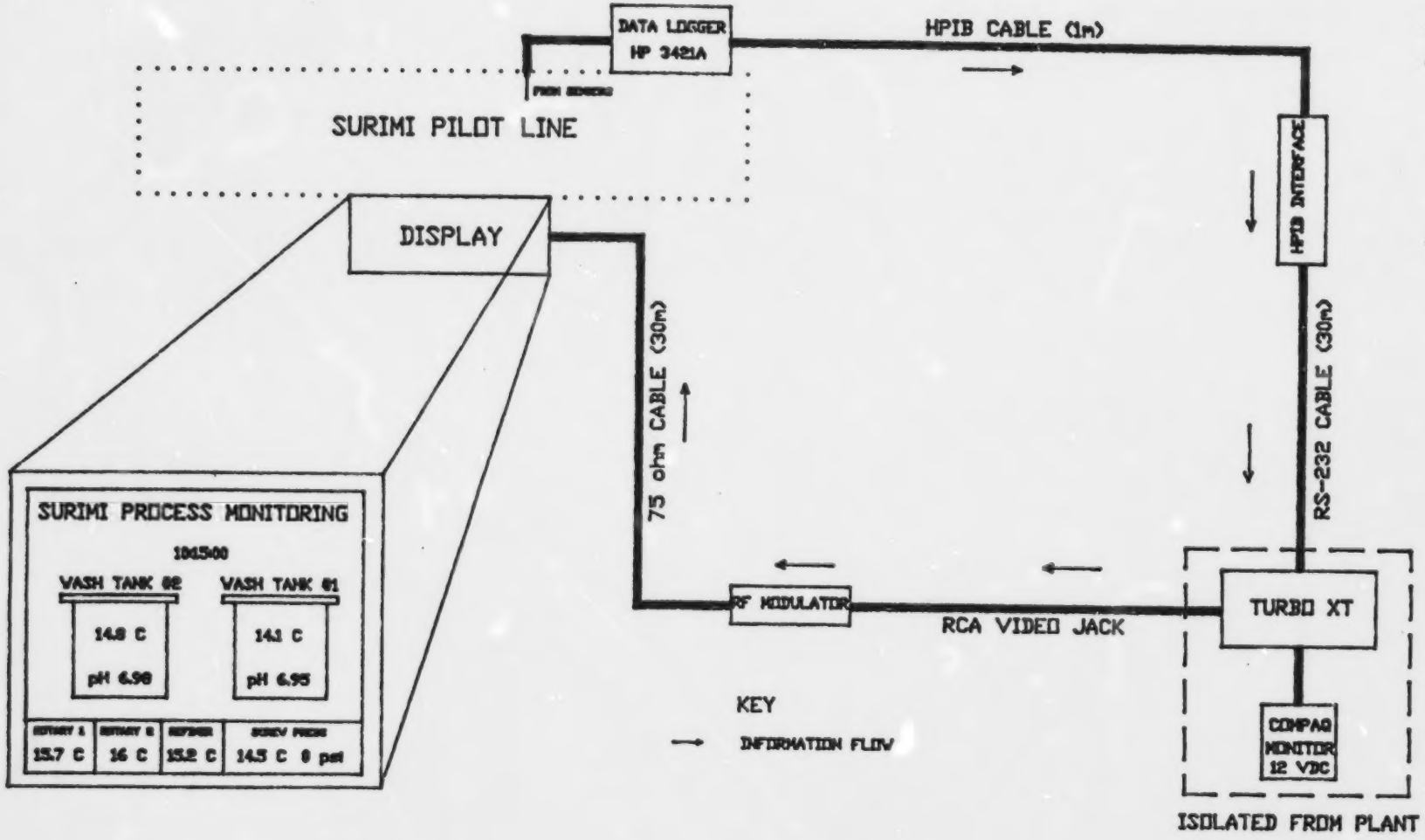


Figure 2.1 Surimi Process Monitoring Equipment Layout

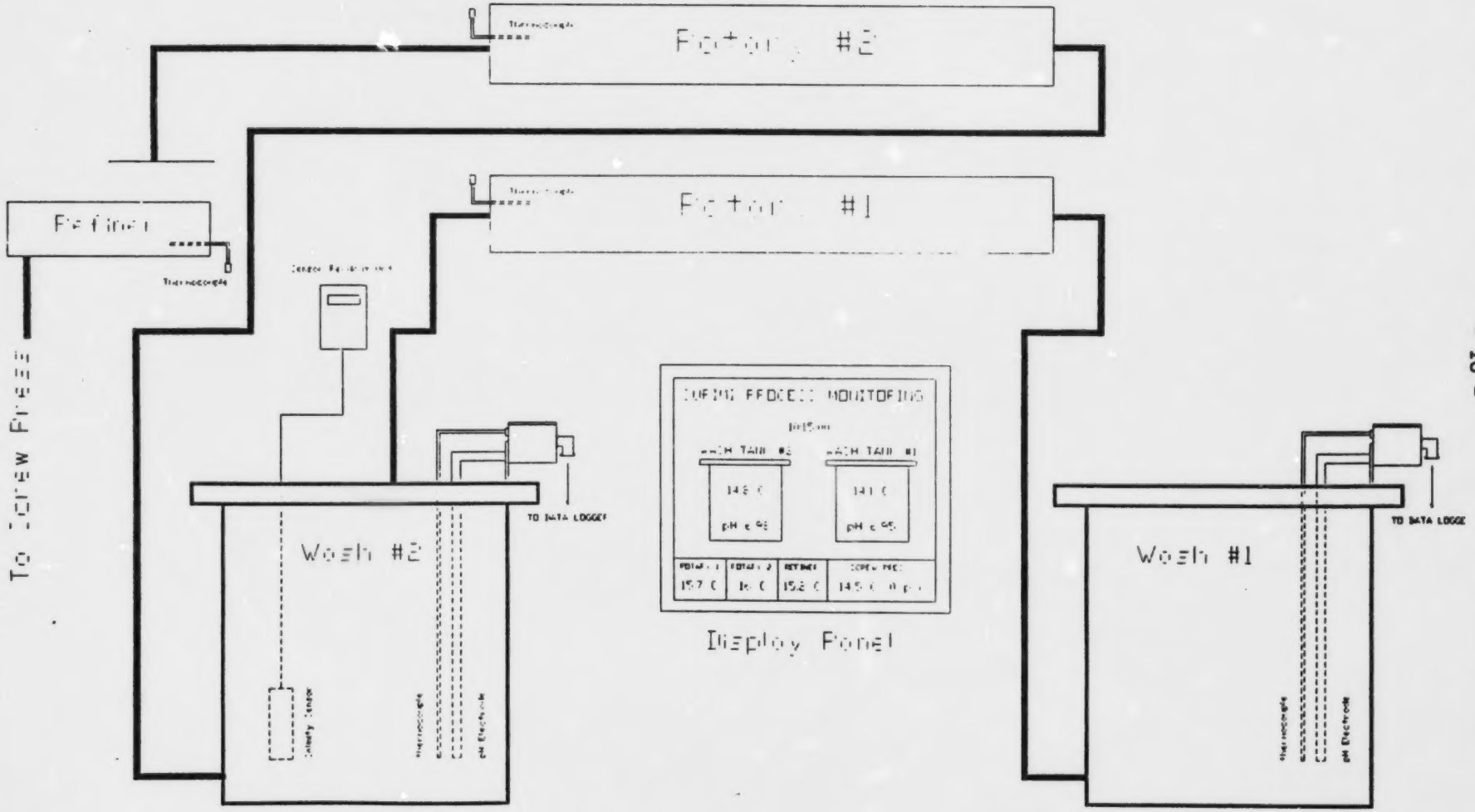


Figure 2.2 Surimi Process Monitoring Display Panel Location

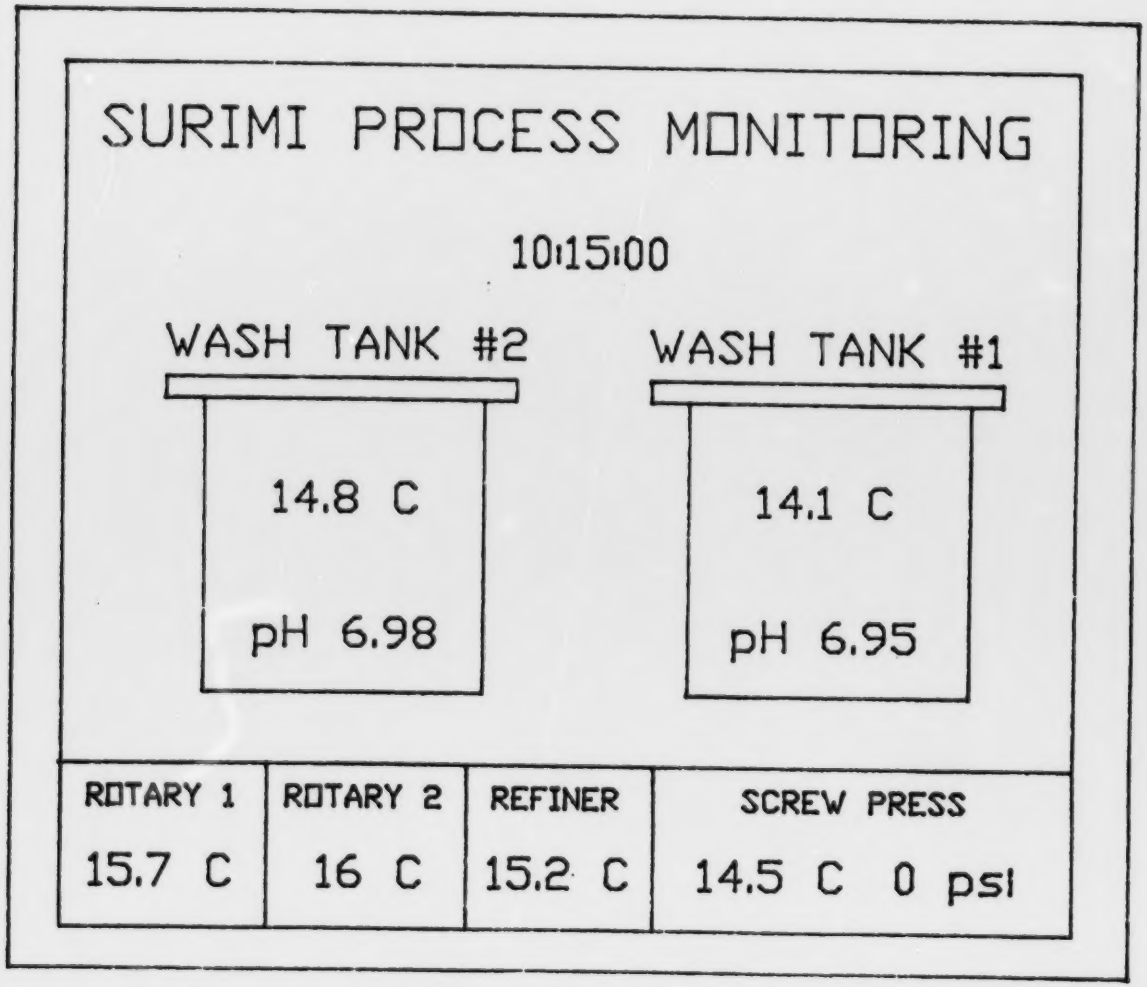


Figure 2.3 Surimi Process Monitoring Display

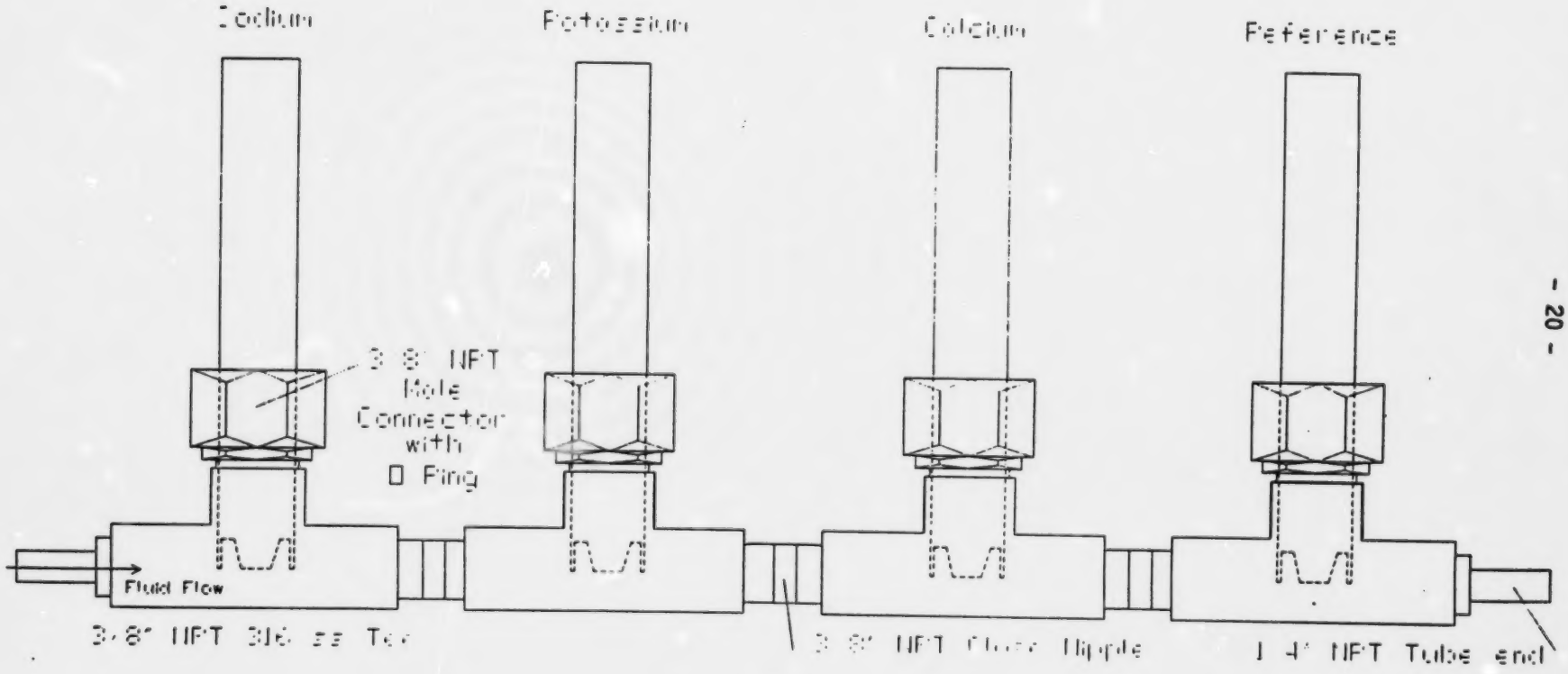


Figure 2.4 Specific Ion Electrode Manifold

pH Electrode Mount

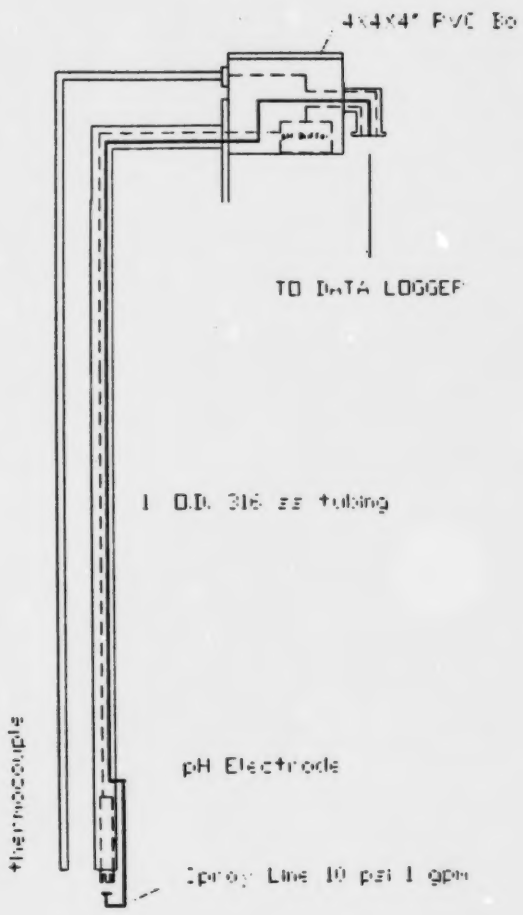
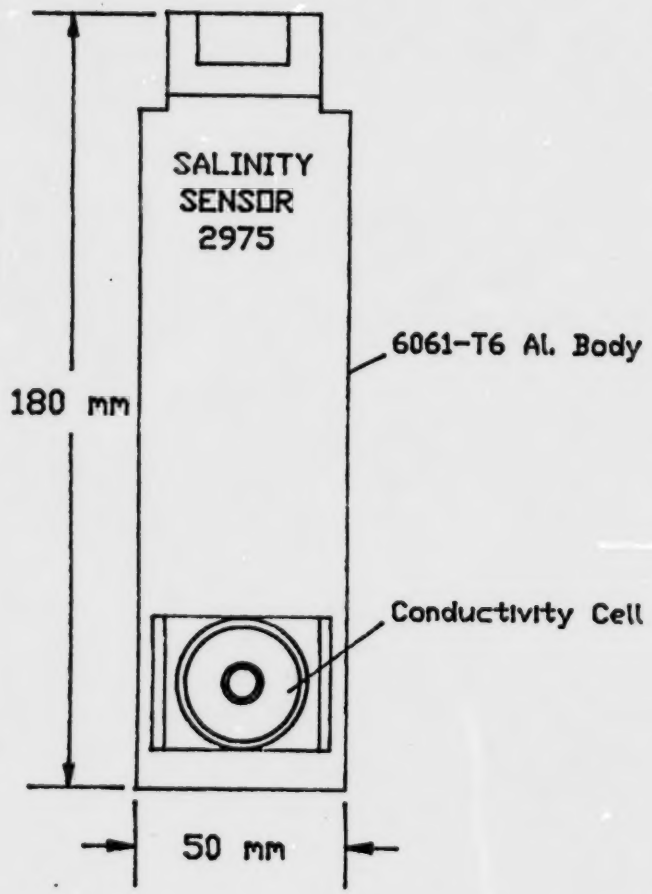


Figure 2.5 pH Electrode Mount



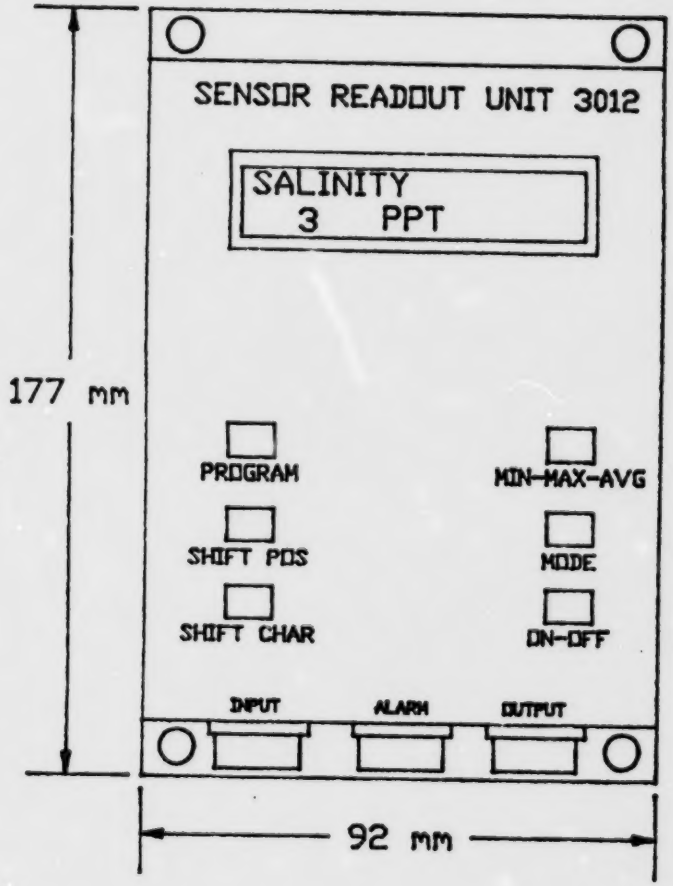


Figure 2.6 Aanderaa Instruments Salinity Sensor

3.0 EXPERIMENTAL WORK

3.1 Introduction

From the previous surimi project (Canpolar, 1987), critical control points were identified as useful for manipulation of surimi textural properties. On the basis of 1986-87 project results, a series of experiments was designed to complete the required process control information.

The rationale for the experimental design was to focus on the controlling parameters: pH, wash cycle, salinity and to determine the optimal processing conditions for each.

3.2 Methods

In all, 25 experimental runs, all of which are outlined in Table 3.1, were performed using 20-30 kg starting material (mince) from cod frames and each taking 50 - 60 minutes to complete. All experiments utilized mince from cod-filleting waste, a cheap source of raw material with high potential for surimi processing.

A video monitor incorporated into the system (see Figure 2.2) displayed pH, temp., and pressure data at one minute intervals and later at 30 second intervals for the operator. The real time display made pH control faster and more efficient. The inductive oceanographic salinometer system was separate from the video monitoring system. A liquid crystal display (LCD) attached to the salinity meter displayed salt concentration in parts per thousand (ppt) at two second intervals.

Laboratory analysis was performed on the fresh surimi product, and after three months frozen storage at -18°C (-0.5°F).

Due to physical limitations in the lab., fresh surimi samples were actually frozen for 3-4 days before being analyzed. Project time did not permit frozen storage of all samples for the full three month period. Because of these time constraints, samples from runs performed late into the project had to be analyzed after 1-2 months frozen stage. In the following text, "fresh" analysis refers to samples analyzed after three days frozen storage:

Figure 3.1 is a flow diagram of the surimi process that was used from raw material through to freezing.

1. Firstly, fresh cod frames from a filleting operation were trimmed to remove the section containing kidney material.
2. Meat was separated from bones using a BAADER 694 deboner with 5 mm drum pore size. Meat was occasionally held in plastic bags on ice for as long as four hours.
3. Mince fish was fed into the first wash tank or "leach" tank where it was mixed with three parts water to one part mince for 10 minutes. pH of the mixture was adjusted to 6.0 using 0.6 N hydrochloric acid (HCl).
4. Mince and water was pumped to a rotary sieve where it was rinsed and drained.
5. Drained mince was fed directly to the second wash tank or "saline" tank at the same mixture ratio as the first leach tank. 0.3% sodium chloride (NaCl) was added to mixture which was again adjusted to pH 6.0 using 0.6N HCL.
6. From the saline tank, mince was pumped to a second rotary sieve and then fed into a refiner and onto the screw press for de-watering.

7. Dewatered mince was then blended with cryoprotectants; 4% sorbitol, 4% sucrose and 0.3% sodium tripolyphosphate ($Na_5P_3O_{10}$) pH 9.0 and then frozen.

Appendix B documents a standard testing procedure for surimi. Tests are divided into compositional and functional property test. Some of these tests, such as protein and lipid determination, were not necessary and were omitted. Figure 3.2 is the standard method of preparing kamaboko for laboratory testing.

It was standard procedure to adjust the moisture content of the surimi to 80% for kamaboko preparation and analysis. If the moisture level was above 80%, no change was made since the moisture level could not be reduced without altering the protein structural properties. Tests were performed on both raw and cooked products. Surimi gels were cooked at three different temperatures; 40°C (105°F), 60°C (140°F) and 90°C (195°F), since different enzymes are activated at each temperature.

A schedule of experiments is listed in Table 3.1 The following discussion provides a rationale:

3.2.1 pH

pH is a factor in controlling moisture content of surimi and some textural properties of the kamaboko products. Past studies indicated that buffering the pH of mince from cod fillets to pH 6.0 - 6.2 would favorably decrease the moisture content of surimi (Canpolar, 1987).

It was necessary to perform a series of "runs", varying the pH level in each to arrive at an optimum value. Three runs were performed at pH 6.0, 6.5 and 7.0. The optimal pH value was determined from lab analysis results and was held constant in runs to follow.

3.2.2 Wash Cycle

It was also necessary to determine the optimal washing cycles for the surimi system. Surimi research (Okada, 1986) indicated the critical parameter in washing cycles is not related to the length of time of the wash or the ratio of water to mince, but rather to the number of washes.

To satisfy this end, a series of four experiments were conducted; a 2x10 min., 3x5 min, 3x10 min., and 2x5 min. washes at differing water to mince ratios.

3.2.3 Salinity

Salinity also affects both H_2O content and textural properties of surimi/kamaboko (as did pH). The purpose of this series was two-fold; (1) to test the effect of salt versus no salt added to the final wash, and (2) to test the effects of different salts; sodium chloride (NaCl), potassium chloride (KCl) and potassium phosphate (K_3PO_4). A large proportion (9 runs) of the schedule was devoted to this study.

3.2.4 Raw Material Preparation

Surimi made from mince from whole frames and from trimmed frames differed in several respects. Trimming the cod-frame removed kidney and most blood from the frame, thus reducing the amount of darkening of the flesh as well as the amount of degradation.

Most "runs" were performed using trimmed frames, while whole frames were used as a comparison.

Freezing is an alternative to using fresh mince to produce surimi especially in summer months when high temperatures catalyze autolytic and microbial spoilage in fresh fish mince. This would be important in a situation where many feeder plants would supply one main surimi processing plant as fresh transportation is difficult. The possibilities of freezing the cod frames versus freezing the mince were examined.

The final runs of the project were concerned with comparing surimi made from fresh and frozen mince previously washed in Canpolar's Mince Washer. The addition of phosphate to mince as a cryoprotectant was also briefly investigated.

3.3 Results and Discussion

Tables 3.2 and 3.3 are complete results of fresh (3 day) and frozen (3 month) laboratory analysis. Raw data for each experimental run is included in Appendix A. Graphical representation of temperature and screw press pressure as a function of time are also included in Appendix A. Temperature and screw press pressure results were discussed fully (Canpolar, 1987).

Table 3.4 shows the moisture content of the surimi at the following points: screw press output, after the addition of cryoprotectants, at fresh (3 day) analysis and at frozen (3 month) analysis.

The first three (3) scheduled runs were a comparison of surimi from whole frames and that of trimmed frames. All three (3) runs were performed at pH 7.0 and resulted in high water content. Runs one and three were analyzed but had too high a water content (82%) to have any gel strength. Run two was discarded because of very high water content, (approximately 90%). These results indicated the necessity of controlling

moisture content, initially by adjusting the pH of the cod mince below the normal level of pH 7.

3.3.1 pH

A series of three (3) pH runs were performed at pH 6.0, 6.5 and 7.0.

As shown in Figure 3.3, the lowest moisture content was found in run five using pH 6.0. Although Run six (pH 6.5) produced a slightly higher shear strain value, its moisture, content was slightly higher and its stress value was lower than that of run five (see Table 3.2). pH 6.0 was chosen as optimum. Results from analysis after three month frozen storage proved this to be the optimal choice since the product was still functional with shear strain value of 1.4 where run six at pH 6.5 had lost its functionality (see Figure 3.7). This corresponds with observation from Canpolar, 1987) that 6.0 - 6.2 is an optimal pH level.

Figure 3.4 shows the general difference in moisture level resulting from leaching at pH 6 compared with leaching at pH 7.

The direct relationship of pH as a controlling factor of moisture content of surimi is shown in Figure 3.5. Decreased pH levels in leaching process will decrease H_2O content by reducing swelling ability of myofibrillar protein, thereby making dewatering more efficient. This trend continues at pH levels below 6.0. However, according to Sonu and other authors, gel-forming ability declines sharply for pH levels less than 6.0 (Sonu, 1986).

Results from fresh analysis indicated a pH increase of approximately one unit occurred after the addition of cryoprotectants.

Since the pH for the majority of runs was controlled at pH 6.0, the pH after cryoprotectants were added was about seven or higher. According to Sonu (1986), highest resistance to freeze denaturation of actomyosin, the principal component of myofibrillar protein, occurs at pH level slightly above 7.0. The reason for the increase in pH is the cryoprotectant $Na_5P_3O_{10}$ which has a pH of about 9.0 - 10.0.

Results from 1986 - 87 surimi project indicated that at pH 6, the screw press operated more efficiently. This was confirmed in the course of these experiments. In order to achieve high screw press pressure, pH must be adjusted to near pH 6.0, in turn, controlling the moisture content. For example, at pH 7, most moisture in surimi exists as "bound" moisture, and very little as "free" moisture. In this case, where "bound" moisture cannot be removed, high pressures cannot be achieved because the product extrudes through perforations in the screw press wall. At pH 6, more of the bound water is released and high pressure can be reached in the screw press because separation of water from meat occurs.

As previously stated, adjustment of pH was used to control final moisture content which in turn determined, within limits, the textural property of the product. A definite trend can be seen in Figure 3.6 where products with moisture content between 75% and 82% showed increasing strain values as moisture content increased. It was determined that 82% is a cutoff point, beyond which the surimi from frame material lost all gel strength. This is a most important relationship since it is a control guide for adjusting pH to obtain the desired texture. Exceptions to this trend (runs 20 - 25) are attributed to differences in raw material properties that are probably of a seasonal nature.

Further evidence of the trend was seen in results of the analysis

of run one, fresh and after three month storage analyses. The trend in Figures 3.6 and 3.7 shows that strain value steadily increased as moisture content increased up to 82%. Beyond 82% (or pH 7.5) there was no strain value as gel strength was lost. This was the case in the fresh analysis of run one because its H_2O content was 82.4% and pH 7.61, slightly above the maximum limit for good surimi. After three months frozen storage, its moisture content and pH level decreased to 81.8% and 7.39, falling within the limits for good surimi. Its corresponding strain value was quite high at 2.56, and it fit the trend perfectly as shown in Figure 3.7.

3.3.2 Wash Cycle

A most important part of surimi processing is the leaching out of undesirables; i.e., blood, TMAO, oils, inorganic salts and other flavor compounds as well as sarcoplasmic protein. The water soluble protein of fish flesh, when present, impedes the gel forming ability of surimi (Sonu, 1986).

The next four (4) experimental runs (7, 8, 9, 10) involved the determination of an optimal wash cycle. Each were different combinations of wash time and number of washes (see Table 3.1). According to recent studies (Sonu, 1986), the resulting surimi gel strength increases as the number of wash cycles are increased. These studies utilized mince from whole fish, dressed fish or fillets. In this project, mince was taken from cod frames which have only short meat fibers left on the bone after the filleting process. Because of the shorter fibers, leaching probably occurs faster with frame mince than mince from fillets. Although the best

results were achieved from run seven, a 2x10 minute washing cycle results from run 10 were close behind with very little decrease in strain value and an equal score of five on fold test (see Table 3.2). The 2x10 minute wash cycle was taken as optimum and used throughout the remainder of the project.

3.3.3 Salinity

The addition of salt to the final wash cycle was found to affect moisture content to textural properties of surimi. As is already known, salt concentrations of 0.1 - 0.6% will reduce excess hydration of meat (Sonu, 1986). At pH 6.0, as previously stated, the moisture content of surimi was sufficiently low. The use of 0.3% NaCl in the final wash reduced the moisture content slightly further (see Figure 3.4). Results from analysis also indicated a slight reduction in strain values when salt was used in the final wash (see Figure 3.8). Exceptions were runs five and six where raw material quality may have varied.

Additional runs were performed to evaluate the effects of salts on the gel strength of the surimi. Runs were performed utilizing KCl and K_3PO_4 to find their effect upon processing of surimi relative to the effect of NaCl and to determine whether these salts would affect properties of surimi after frozen storage. Results indicated no significant change in gel strength or moisture content during fresh analysis from runs utilizing potassium salts compared with runs utilizing NaCl.

Frozen storage results indicated slight decreases in strain values for those runs using NaCl. Similar decreases were observed for potassium salts. In Figure 3.9 (Runs 16, 17 and 18) were performed using the

different salts as shown in the legend. A similar decrease trend in strain value was observed for all three.

3.3.4 Raw Material Preparation

Raw materials handling procedures such as freezing frames, pre-washing mince and freezing washed mince with and without cryoprotectants were all evaluated in runs 20 through 25. Recent studies (Chandra, 1987) concluded that whole frames processed under the same conditions as trimmed frames will result in lower strain values. No reliable results were obtained. Control runs 21 and 22, processed under similar conditions as previous runs, produced results that were not comparable to previous results for similar materials. The associated experimental runs (20, 23, 24 and 25) produced results similar to the control runs 21, 22. There was probably some seasonal variability in the raw material. All of the anomalous experimental results were obtained in February. No conclusions were drawn from these experiments.

Table 3.1 Surimi Run Schedule

RUN #	TYPE	RUN DATE
1	WHOLE FRAMES - pH 7	11/03/87
2	TRIMMED FRAMES - pH 7	11/04/87
3	TRIMMED FRAMES - pH 7	11/05/87
4	pH SERIES 7.0	11/18/87
5	pH SERIES 6.0	11/18/87
6	pH SERIES 6.5	11/18/87
7	WASH CYCLES 2*10 min 3:1 WATER:MINCE	11/24/87
8	WASH CYCLES 3*5 min 2:1 WATER:MINCE	11/24/87
9	WASH CYCLES 3*10 min 2:1 WATER:MINCE	11/25/87
10	WASH CYCLES 2*5 min 3:1 WATER:MINCE	11/25/87
11	SALINITY:pH 6 / 0.3% saline	12/08/87
12	SALINITY:pH 6 / 0% saline	12/08/87
13	SALINITY:pH 7 / 0.3% saline	12/18/87
14	SALINITY:pH 7 / 0% saline	12/18/87
15	OPT. pH/WASH 0.0% sal.	01/21/88
16	OPT. pH/WASH 0.3% NaCl	01/21/88
17	OPT. pH/WASH 0.3% KCl	01/26/88
18	OPT. pH/WASH 0.3% pot. phosphate	01/26/88
19	OPT. pH/WASH 0.0% sal.	01/26/88
20	WH. FROZEN FRAMES (froz. 1 mo.)	02/04/88
21	WHOLE FRAMES	02/05/88
22	TRIMMED FRAMES	02/05/88
23	FROZEN WASHED MINCE	02/12/88
24	FRESH WASHED MINCE	02/19/88
25	FROZEN WASHED MINCE (0.3% polyphosphate)	02/26/88

Table 3.2 Surimi Product Fresh (3 days) Analysis.

SURIMI PRODUCT FRESH ANALYSIS																				
RUN #	DATE	% H2O	pH	COLOUR (L VALUE)				FOLD TEST			FRGN	YIELD	STRESS (kPa)			STRAIN (mm/mm)				
				RAW	40 C	60 C	90 C	40 C	60 C	90 C	ELEM	80% H2O	40 C	60 C	90 C	40 C	60 C	90 C		
1	NOV 3	82.4	7.61	46.2	46.2	70.5	70.3	1	1	1	8	10.4		no	gel	str				
2		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		no	gel	str				
3	NOV 5	87.1	8.92	50.4	n/a	n/a	n/a	n/a	n/a	n/a	7	n/a		no	gel	str				
4	NOV 18	84.9	7.70	53.0	72.2	72.8	72.8	5	5	5	8	10.5		no	gel	str				
5	NOV 18	79.2	7.28	53.0	70.9	70.7	70.7	5	3	5	8	9.3	13.20	8.00	10.50	2.07	1.60	2.21		
6	NOV 18	81.0	7.47	52.3	70.9	70.8	70.3	5	3	5	7	10.4	7.20	5.30	7.40	2.37	1.69	2.39		
7	NOV 24	76.7	7.10	46.9	67.4	68.4	n/a	5	3	5	7	12.7	16.80	12.60	19.30	1.70	1.36	1.87		
8	NOV 24	76.0	6.79	47.7	70.4	71.5	72.2	2	2	2	7	11.6	9.70	4.30	11.60	1.38	0.67	1.62		
9	NOV 25	77.9	6.81	49.5	70.7	72.2	72.1	4	2	4	7	11.4	8.50	4.00	7.70	1.74	1.12	1.82		
10	NOV 25	78.9	6.88	46.0	69.9	70.4	69.8	5	1	5	7	15.6	7.70	n/a	5.20	1.71	n/a	1.76		
11	DEC 8	77.2	6.91	49.7	71.0	72.5	71.6	2	2	2	9	12.4	6.60	3.20	6.20	1.39	0.84	1.51		
12	DEC 8	80.6	6.98	46.4	72.7	72.5	71.8	4	2	5	8	14.3	7.20	n/a	6.90	1.88	n/a	2.07		
13	DEC 18	85.0	8.03	53.8	72.7	70.6	71.9	1	1	1	8	n/a		no	gel	str				
14	DEC 18	85.9	7.61	53.6	72.3	70.0	71.4	1	n/a	n/a	8	n/a		no	gel	str				
15	JAN 21	78.5	6.84	44.9	70.0	70.0	69.1	3	2	5	7	7.2	5.30	4.11	7.83	1.56	1.25	1.80		
16	JAN 21	74.8	7.07	42.0	67.4	65.7	63.0	2	1	2	7	10.9	5.37	4.50	6.01	0.97	1.05	1.58		
17	JAN 26	77.2	7.01	41.2	66.4	66.3	67.4	2	1	2	6	15.3	8.27	4.90	7.58	1.55	1.13	1.67		
18	JAN 26	75.0	6.70	43.3	67.5	67.7	66.6	1	1	1	7	11.3	4.90	n/a	4.95	1.10	n/a	1.35		
19	JAN 26	81.7	6.89	46.0	67.6	68.4	66.9	5	1	5	6	15.6	7.83	3.74	7.85	2.14	1.29	2.26		
20	FEB 4	80.4	7.02	48.1	58.4	58.3	58.6	2	2	2	5	n/a	8.06	7.53	8.93	0.74	0.83	0.81		
21	FEB 5	75.9	6.80	36.2	55.5	54.7	55.3	2	1	1	7	n/a	n/a	3.53	3.16	n/a	0.81	0.82		
22	FEB 5	75.4	6.90	43.2	64.1	62.9	64.1	2	2	2	4	n/a	4.37	3.16	6.74	1.08	1.13	1.29		
23	FEB 12	81.5	7.09	49.1	64.9	64.9	65.0	2	2	2	4	n/a	4.66	3.37	4.05	1.12	1.01	1.07		
24	FEB 19	72.1	6.75	47.7	62.5	61.7	63.8	1	1	1	7	n/a		no	gel	str				
25	FEB 26	83.9	7.03	49.7	n/a	n/a	n/a	n/a	n/a	n/a	7	n/a		no	gel	str				

Table 3.3 Surimi Product Frozen (3 months) Analysis.

SURIMI PRODUCT FROZEN (3 mon) ANALYSIS

RUN #	DATE	% H2O	pH	COLOUR (L VALUE)				FOLD TEST			FRGN ELEM	YIELD 80% H2O	STRESS (kPa)			STRAIN (mm/mm)		
				RAW	40 C	60 C	90 C	40 C	60 C	90 C			40 C	60 C	90 C	40 C	60 C	90 C
1	NOV 3	81.8	7.39	47.3	70.9	70.0	69.4	3	2	5	6		5.05	n/a	5.32	1.79	n/a	2.56
2	n/a																	
3	NOV 5	86.3	8.26	53.2	n/a	n/a	n/a	n/a	n/a	n/a	6			no	gel	str		
4	NOV 18	83.7	7.70	52.2	74.6	74.6	73.3	n/a	n/a	n/a	8			no	gel	str		
5	NOV 18	78.1	7.2	47.9	72.5	72.2	71.1	2	2	2	8		5.85	2.26	5.64	1.42	0.76	1.47
6	NOV 18	81.4	7.35	48.0	71.3	71.3	70.2	n/a	n/a	n/a	9			no	gel	str		
7	NOV 24	77.2	6.92	47.8	70.7	70.2	70.4	2	1	2	7		4.69	9.16	8.95	1.15	1.43	1.62
8	NOV 24	75.8	6.76	49.7	66.6	71.6	71.2	n/a	n/a	n/a	6			no	gel	str		
9	NOV 25	76.8	6.81	51.7	n/a	n/a	n/a	n/a	n/a	n/a	7		n/a	n/a	n/a	n/a	n/a	n/a
10	NOV 25	78.4	6.82	46.8	72.3	70.6	71.7	1	2	2	6		1.74	4.69	7.58	0.91	1.36	1.63
11	n/a																	
12	DEC 8	81.6	6.83	50.9	70.1	71.3	70.4	n/a	n/a	n/a	8			no	gel	str		
13	n/a																	
14	n/a																	
15	JAN 21	78.6	6.63	45.4	n/a	n/a	n/a	n/a	n/a	n/a	4			no	gel	str		
16	JAN 21	74.9	7.02	42.4	66.6	67.4	66.8	2	2	2	5		7.85	6.87	7.9	0.96	0.89	1.36
17	JAN 26	77.8	6.85	40.5	67.1	66.3	66.8	2	2	3	4		14.75	6.33	12.4	1.44	1.92	1.42
18	JAN 26	75.0	6.47	39.7	67.0	66.9	66.8	2	2	2	5		6.37	6.27	7.74	0.77	0.87	0.78
19	JAN 26	80.5	6.87	42.7	68.3	68.3	66.8	5	3	5	4		10.8	6.95	15.57	1.66	1.11	1.88
20	FEB 4	85.7	7.59	46.7	67.2	65.6	65.8	2	2	2	4			no	gel	str		
21	n/a																	
22	n/a																	
23	n/a																	
24	n/a																	
25	n/a																	

Table 3.4 Moisture Contents (%) At Different Process And Storage Points.

RUN#	SCREW PRESS	AFTER CRYO-PROTECTANTS	3 DAYS ANALYSIS	3 MONTH ANALYSIS
1	87.6	83.4	82.4	81.8
2	-	-	-	-
3	93.9	87.4	87.1	86.3
4	91.6	85.1	84.9	83.7
5	85.5	79.1	79.2	78.1
6	86.8	82.1	81.0	81.4
7	84.0	77.0	76.7	77.2
8	78.9	75.9	76.0	75.8
9	82.0	78.4	77.9	76.8
10	86.5	78.4	78.9	78.4
11	82.6	76.4	77.2	-
12	87.6	81.3	80.6	81.6
13	92.0	84.9	85.0	-
14	93.0	85.8	85.9	-
15	84.0	78.2	78.5	78.6
16	81.3	75.1	74.8	74.9
17	83.3	78.4	77.2	77.8
18	76.4	74.2	75.0	75.0
19	88.7	82.4	81.7	80.5
20	88.1	80.3	80.4	85.7
21	82.8	76.1	75.9	-
22	82.7	75.4	75.4	-
23	89.1	82.2	81.5	-
24	78.0	74.8	72.1	-
25	89.8	86.6	83.9	-

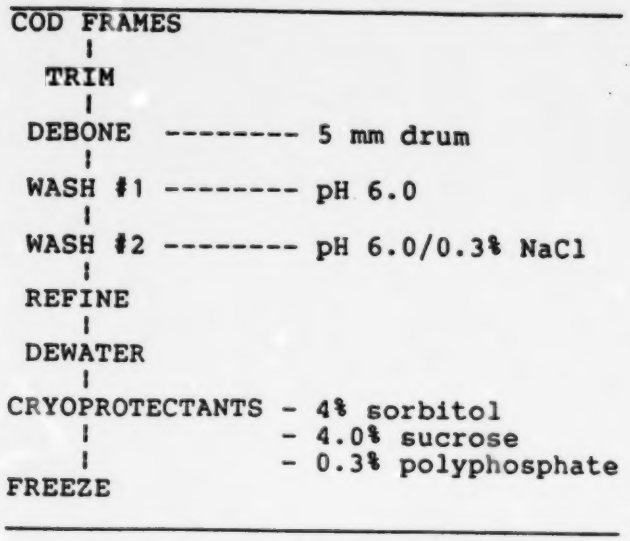


Figure 3.1 Surimi process.

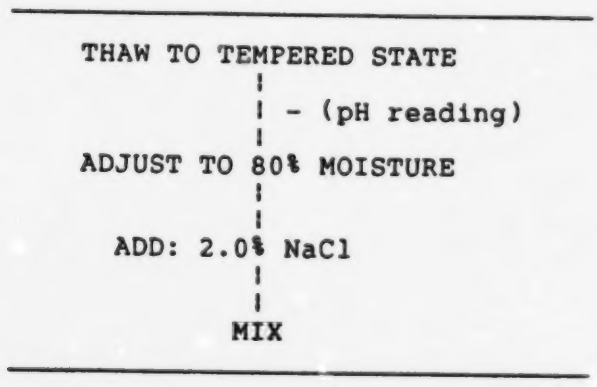


Figure 3.2 Kamaboko process (pre-analysis).

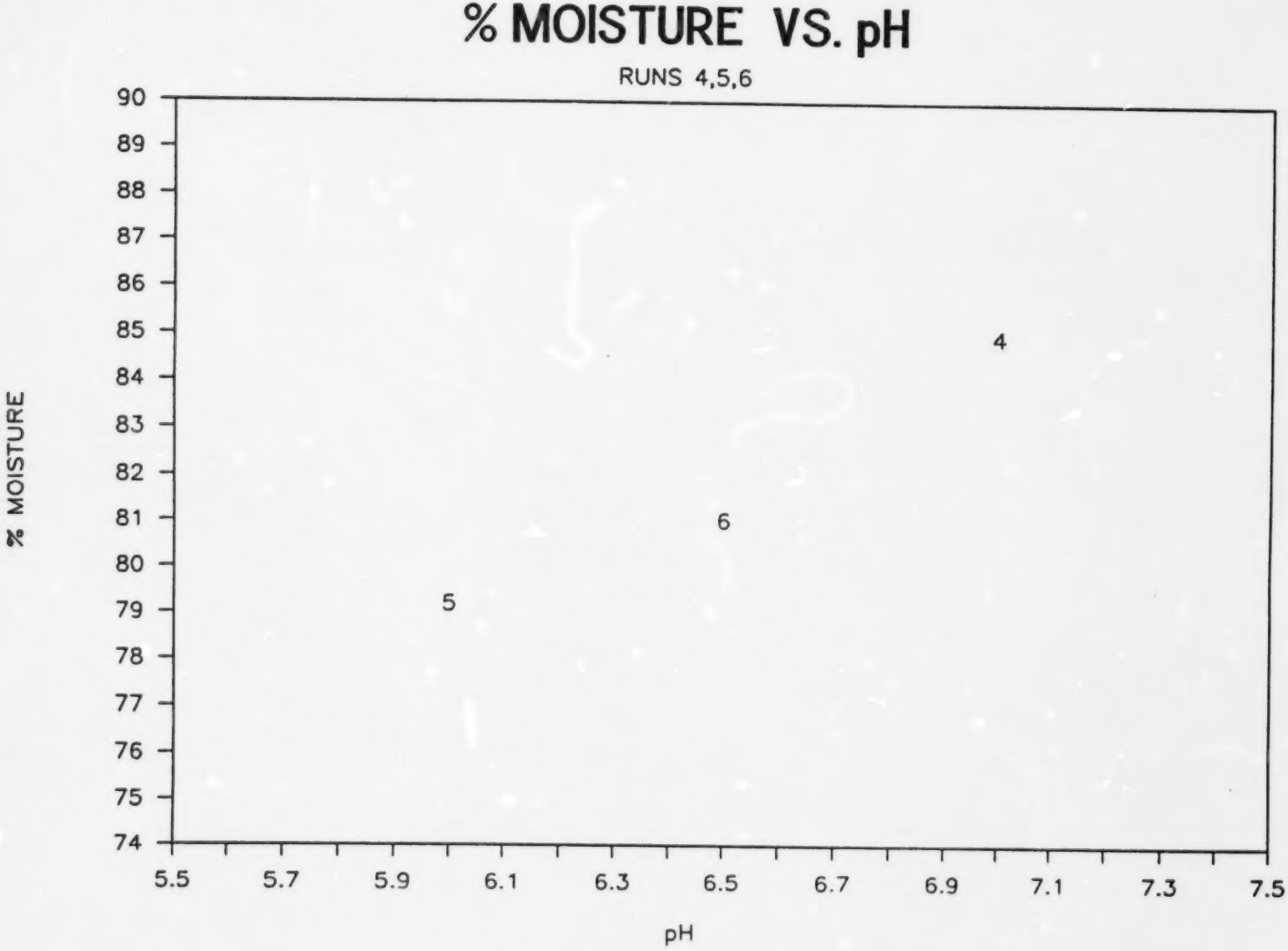


Figure 3.3 Change in H_2O content in determination of optimum pH.

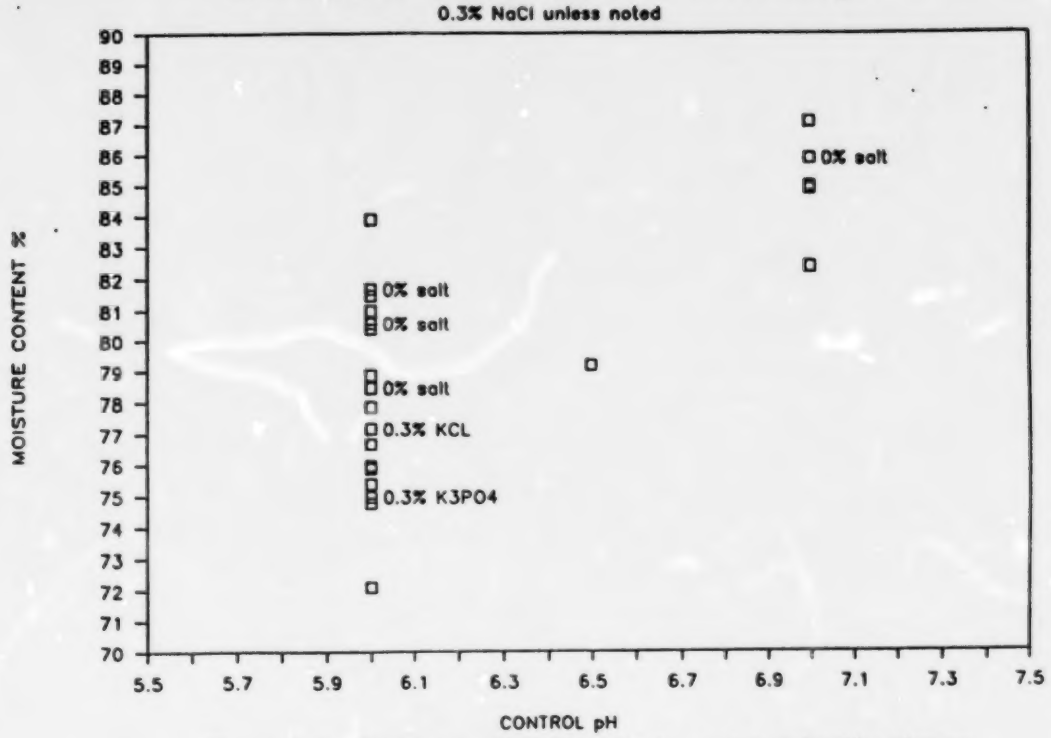


Figure 3.4 Summary of H_2O contents as determined by change in pH and salt.

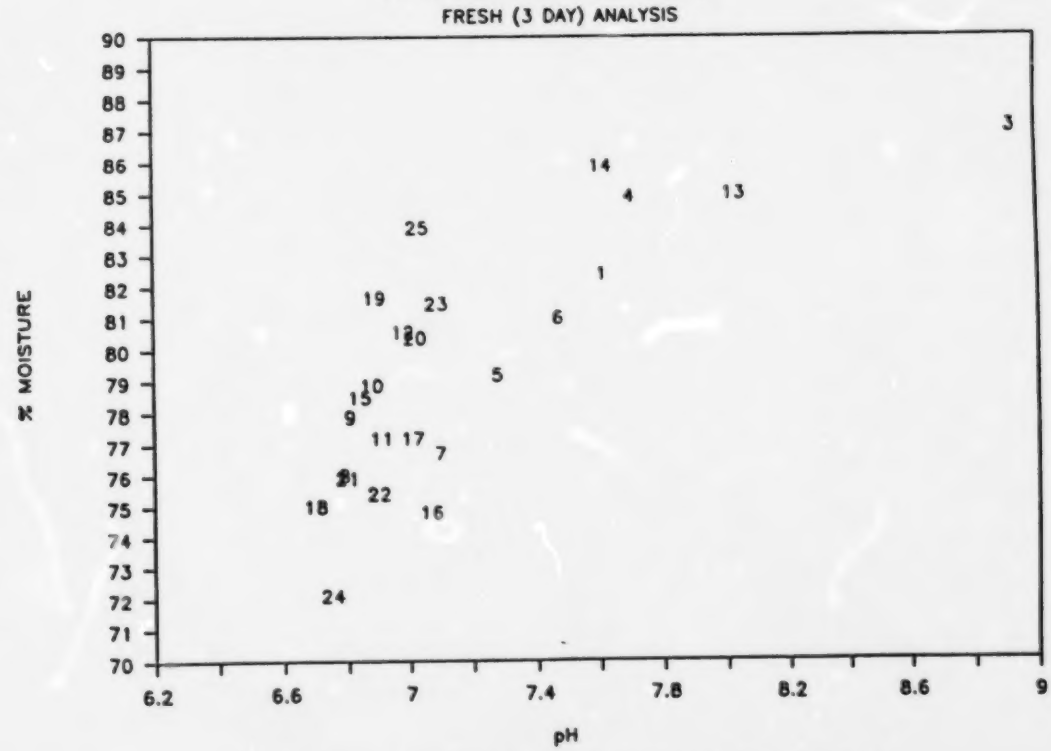


Figure 3.5 The moisture content of surimi increases as pH is increased.

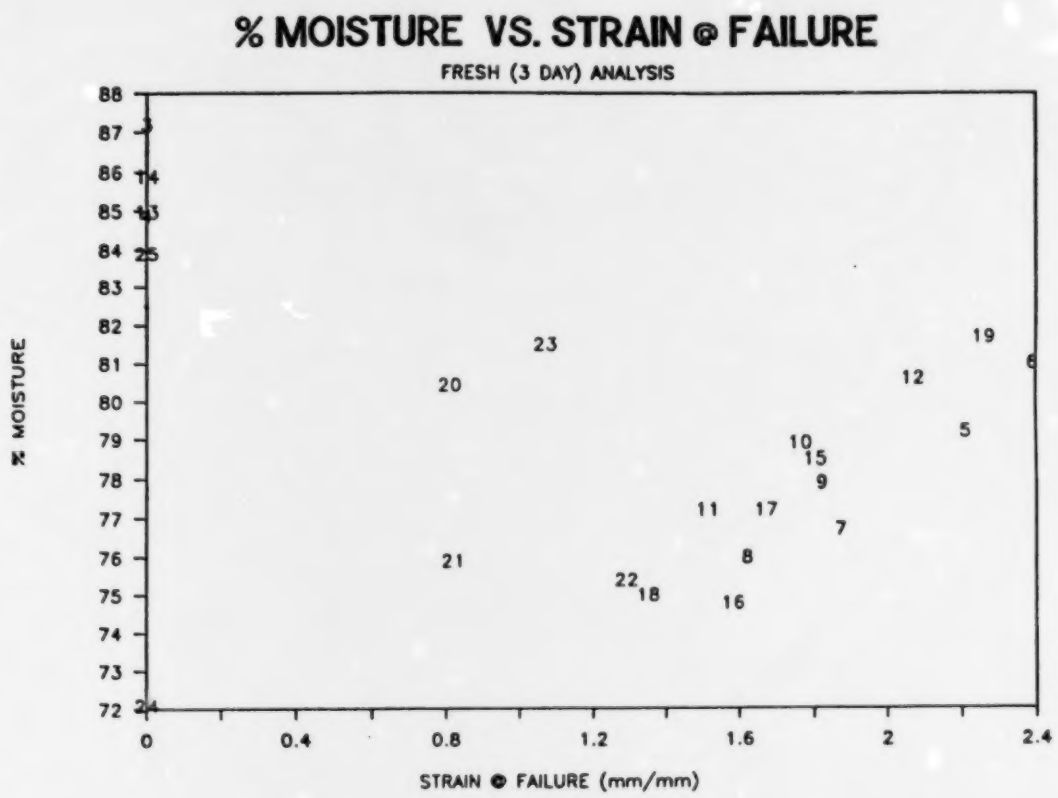


Figure 3.6 The strain value (elasticity) of cod frame surimi follows a definite trend. It increases with moisture content up to 82% (or pH 7.5) at which point it collapses abruptly to zero. pH is directly related to moisture content.

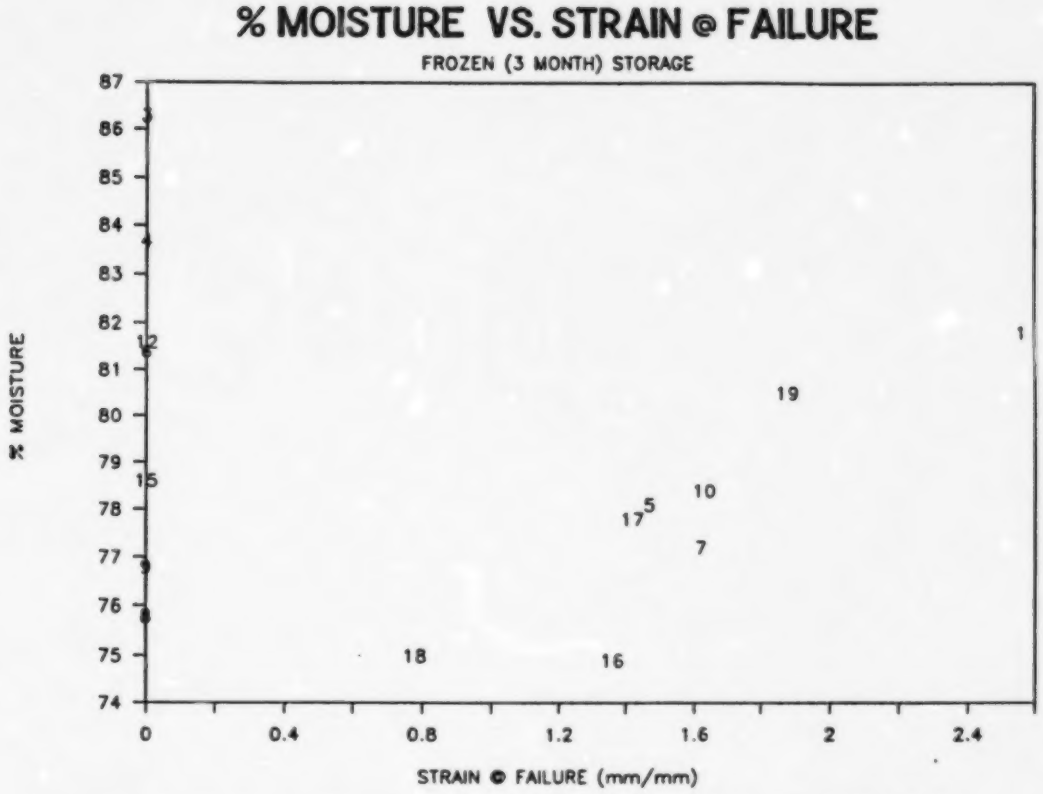
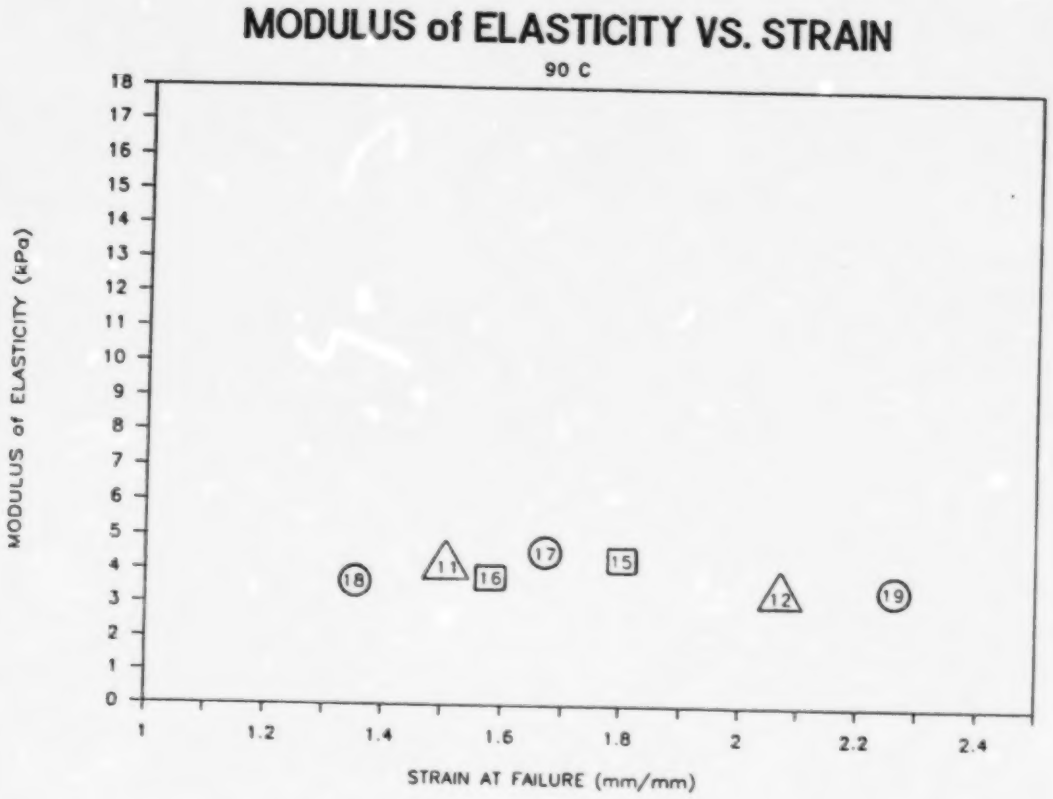


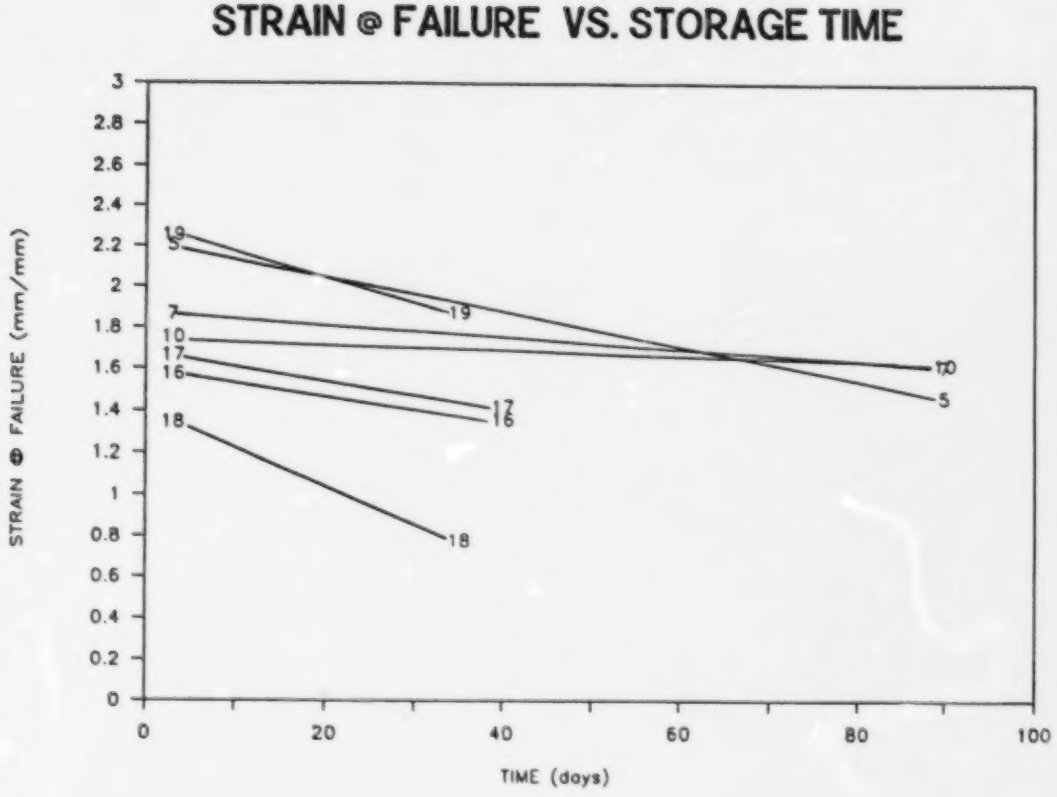
Figure 3.7 The strain value of cod frame surimi decreases slightly in frozen storage but the cut-off point remains at 82% or pH 7.5.



LEGEND:

NO SALT (CONTROL)	SALT
12	11
15	16
19	17
	18

Figure 3.8 The use of salt in the surimi saline wash shows a general decrease in strain value.



LEGEND :

RUN #		SALT USED
5	-	0.3% NaCl
7	-	0.3% NaCl
10	-	0.3% NaCl
16	-	0.3% NaCl
17	-	0.3% KCl
18	-	0.3% K3PO4
19	-	0 % salt

Figure 3.9 A similar decrease in strain value occurs with frozen storage time independent of different saline washes.

4.0 PROCESS INTERPRETATION

Process parameters of importance include:

a) control of surimi production line parameters

b) control of surimi functional/storage properties

Production parameters include:

a) wash duration, water usage

b) pH, salt and chemical additives

c) refiner efficiency

d) moisture content of product

4.1 Washing

Experimental results indicated little significant quality difference between the various washing procedures that were tried. Two, 3:1 washes of five minute duration, ~~gave~~ PRODUCED results similar to more wash cycles or higher water to meat ratios. This result corroborates experimental findings from the previous year's work (Canpolar 1987) indicating that for batch processing the leaching of soluble materials was essentially complete within two minutes.

It is worth noting that mince recovered from frames normally consists of smaller particles than fillet mince. Rapid leaching would be expected for this material.

Assuming equilibration during each wash cycle, two washes at 3:1 water to meat should reduce salts and soluble organics content of the mince below 10% of the original concentration. This appears to be an adequate procedural standard.

Recommended Wash Procedure

Batch 5 min x 1 x 3:1 water:meat

or equivalent for continuous washing

4.2 pH and Salts

The pH of washed frame mince (in combination with salinity) influences both the final water content of the surimi and strain at failure or elasticity of the kamoboko made from the surimi.

Figure 4.1 shows the % water content of raw surimi as a function of pH. Figure 4.2 shows the % water content after addition of cryoprotectants. The correlation between pH, ionic strength and water content is well defined and can be approximated by the following linear equations:

After addition of 8.3% cryoprotectants (4% sorbitor 4% sucrose .3% polyphosphates)

With salt (N_aCl, KCL, K_3PO4):

$$(\% H_2O) = 8.6(pH) + 17.7$$

Without salts:

$$(\%H_2O) = 8.6(pH) + 20.3$$

Screw press operation apparently effects dewatering but does not determine the final water content of the surimi product. Observations from the previous year indicated that screw press dewatering effectiveness was more or less contingent on surimi properties. It is apparent that control of moisture content must take into account; both the salinity and pH of the leaching system.

In addition to controlling the water content of the surimi, pH also independently affects the functional properties of the kamoboko product.

Figure 4.3 shows the effect of pH on strain at failure for kamoboko (adjusted to 80% H_2O). The kamoboko elasticity increases dramatically up to pH 7.5 beyond which it plummets to zero. The abrupt transition is reversible. This relationship is not unique to cod frame materials. Figure 4.4 shows three years accumulated data for cod fillets, frames etc. (Note archived data is given in Appendix F). The maximum kamoboko strain value at pH 7.3 - 7.4 is well defined.

The slope of the pH relationship and the abrupt loss of functional properties above pH 7.5 is not as well defined in the historical data but experimental conditions were not as carefully controlled as in this year's work.

It could be argued that water content rather than pH is a controlling factor. However, Figure 4.5 shows kamoboko strain plotted versus water content for archived data. No trend is evident.

Figure 4.6 shows stress plotted versus $\%H_2O$ for archived data. The lower the water content the higher the stress value. The stress value is uniquely related to water content and is independent of pH. This can be seen from Figure 4.7, showing that for kamoboko made from surimi adjusted to 80% water, pH has no predictable effect on stress at failure.

Figure 4.8 from Okada, 1985, shows a similar stress relationship (gel strength determined by punch test) as in Figure 4.6 for water content for pollock surimi.

4.3 Gel Properties Measurement

The fold test is the traditional commercial assessment of kamoboko gel strength. The punch test has been used for pollock surimi as a laboratory measurement (Lanier et al, 1985). Recent innovations in the U.S. invovled a compression test or torsion test. The data encompassed in this report is referenced to both the fold test and to the torsion test. Direct comparison to other standards is difficult.

The punch test is related to the stress value at failure (Lanier et al, 1986). The fold test relates moderately well to the strain measurement provided by the torsion test (See Figure 4.9).

In general, good quality surimi (fold test 5) exceeds a strain value of 2.0 in the torsion test. The fold test is more or less independent of measured stress at failure. However, it is worth noting that AA pollock surimi normally has a stress value of 40-50 kPa (6-7 psi) (D.D. Hamnan and T.C. Lanier). This value is controllable independent of strain (or fold test) by modifying surimi water content (Figure 4.6).

4.4 Freezer Storage

It was anticipated that pH and ionic strength would affect the freezer storage properties of surimi. Figure 3.9 shows that for the available data there appears to be little or no effect on storage properties due to variation in pH or salt content.

4.5 Process Control Algorithm

The first step in defining a process control algorithm is to set a product specification for the material being processed. The choices for

an operator may be one or all of stress/strain/fold test/water content. A methodology for product specification must be chosen as a basis for the control system input.

There are at least five different methods in use for the assessment of surimi mechanical properties. Lanier, Hamann and Wu reviewed the ITPA, punch and fold tests in relation to the torsion test. Recently Dr. C. Lee has introduced a new compression test and Sano et al., 1986, have proposed a new type of tensile test. The punch test is favoured by Japanese workers.

Each different test has its merits. The torsion test is perhaps the most difficult to perform but is also the most informative of the laboratory testing techniques. Unfortunately, it is difficult to make accurate correlations between the various methods.

The process control algorithm has been arbitrarily established in respect to product specification derived from the torsion test. There appears to be a relationship (albeit poorly defined) between the torsion test and most other tests.

Figure 4.6 indicates the approximate relationship between torsion test parameters and the fold test. In practice, production of the best grade of surimi will require a manufacturer to maximize strain but stress should be optimized at a value of about 50 kPa (7 psi) to meet normal pollock surimi specifications. These set point parameters have been assumed for the process control system.

The overall surimi process recipe (algorithm) is illustrated in Figure 4.10. The colored boxes and circles indicate specific process control points in which chemical manipulation is used to modify processing parameters. The set point values indicated on the circled graphs represent

arbitrarily chosen control values that should result in a surimi product with torsion test stress values of about 20 kPa and strain values above 2.0.

The operating procedure starts with leach tank pH controlled at pH 6.5 by the addition of HCl. At this pH and with salinity 0.3% the water content of the material after dewatering will be about 80% (see Figure 4.1). The addition of 4% sucrose and 4% sorbitol will reduce the water content to about 74% (see Figure 4.2). The moisture content can be adjusted at this time or during kamoboko preparation to a value that results in the desired gel rigidity. In this case the indicated 78% moisture would result in a gel stress value of about 20 kPa (see Figure 4.6).

The pH of the surimi if left at 6.5 would result in a very poor quality brittle gel with little elasticity (see Figure 4.3). The polyphosphate cryoprotectant additive is therefore formulated to shift the pH of the surimi (after dewatering) to a value of about pH 7.3. This pH set point should result in a gel with elastic strain over 2.0 in the torsion test (or a fold test of five as indicated in Figure 4.9).

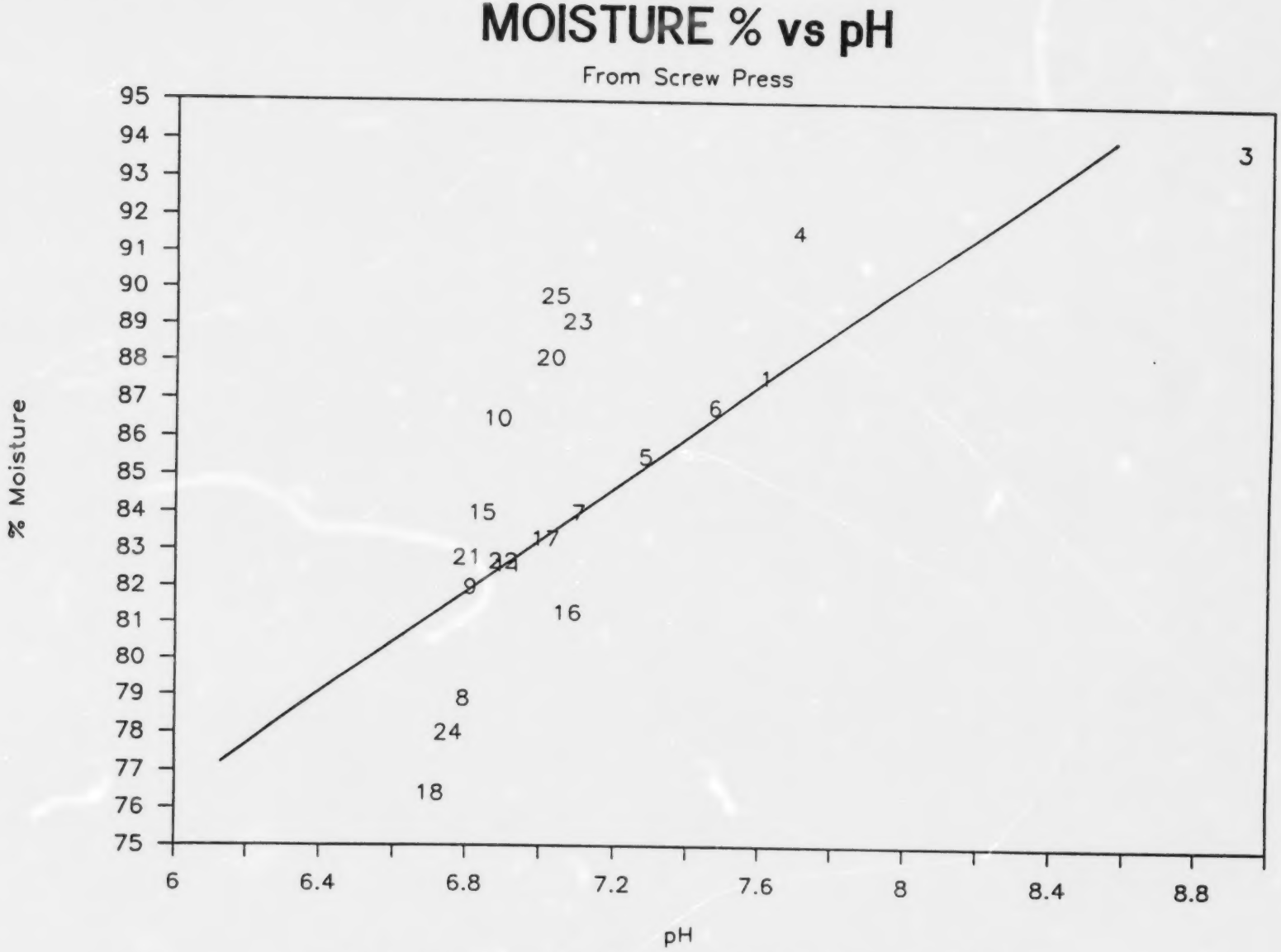


Figure 4.1 The moisture content of dewatered mince prior to the addition of cryoprotectants is deeply correlated to pH. There are some measurement irregularities in this data set. The Figure 4.2 data set consists of duplicate measurements and is preferred

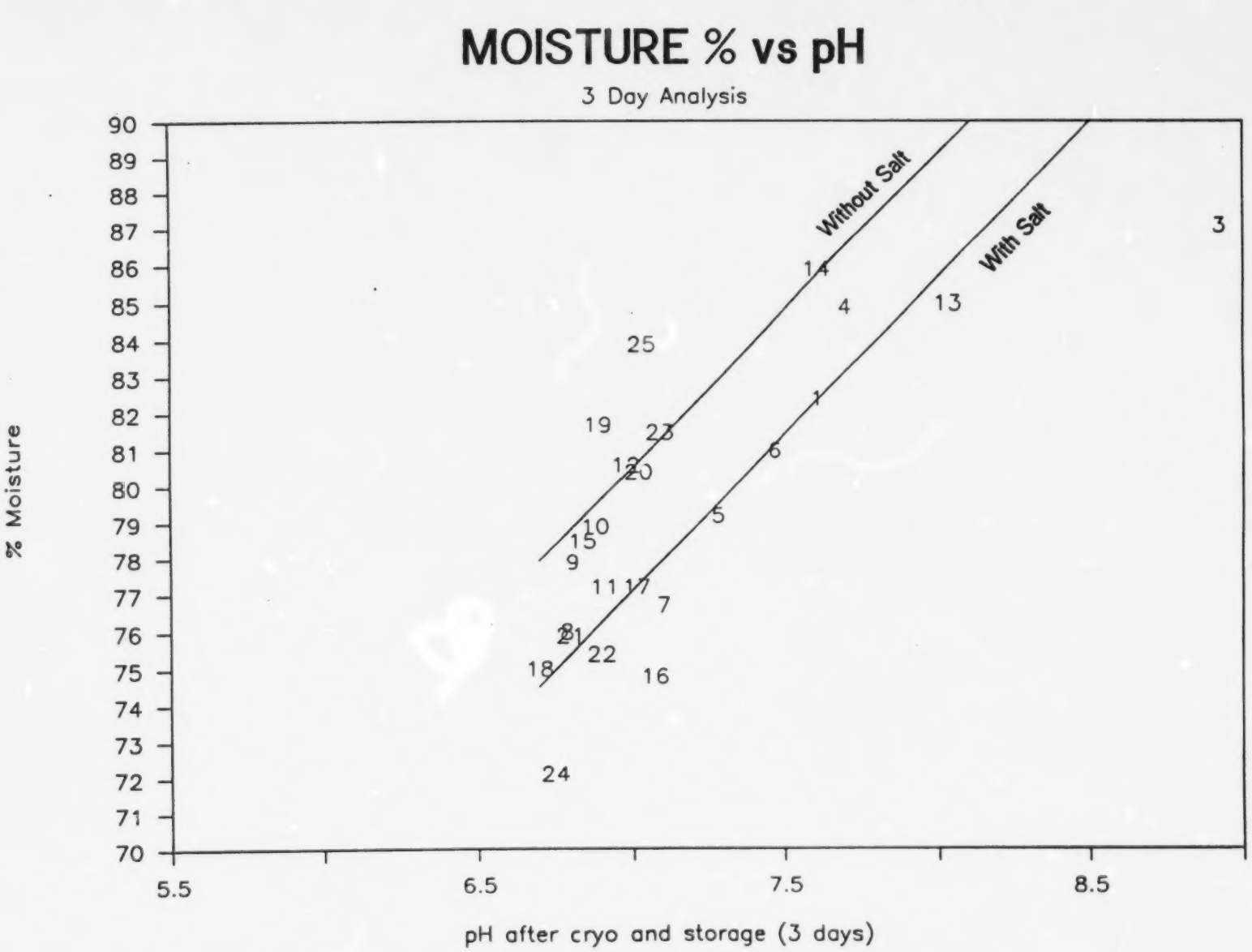


Figure 4.2 The surimi moisture content measured after cryoprotectant addition shows a direct relationship to pH and salt concentration. The alkaline phosphates in the cryoprotectant shift pH by about 0.8 units.

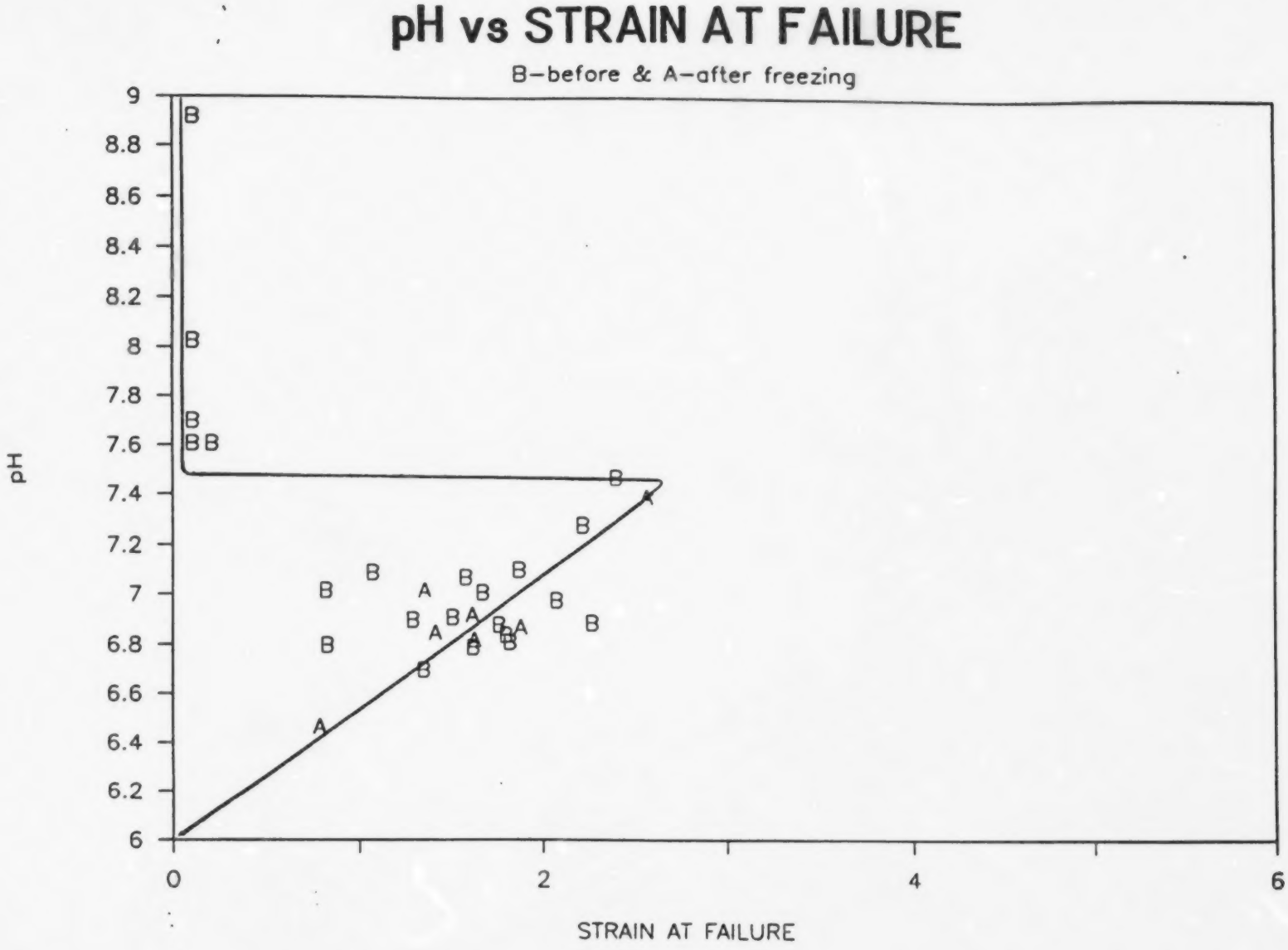


Figure 4.3 The strain value (elasticity) of cod frame surimi follows a clearly defined trend. It increases with pH up to 7.5 at which point the gel strength collapses abruptly to zero.

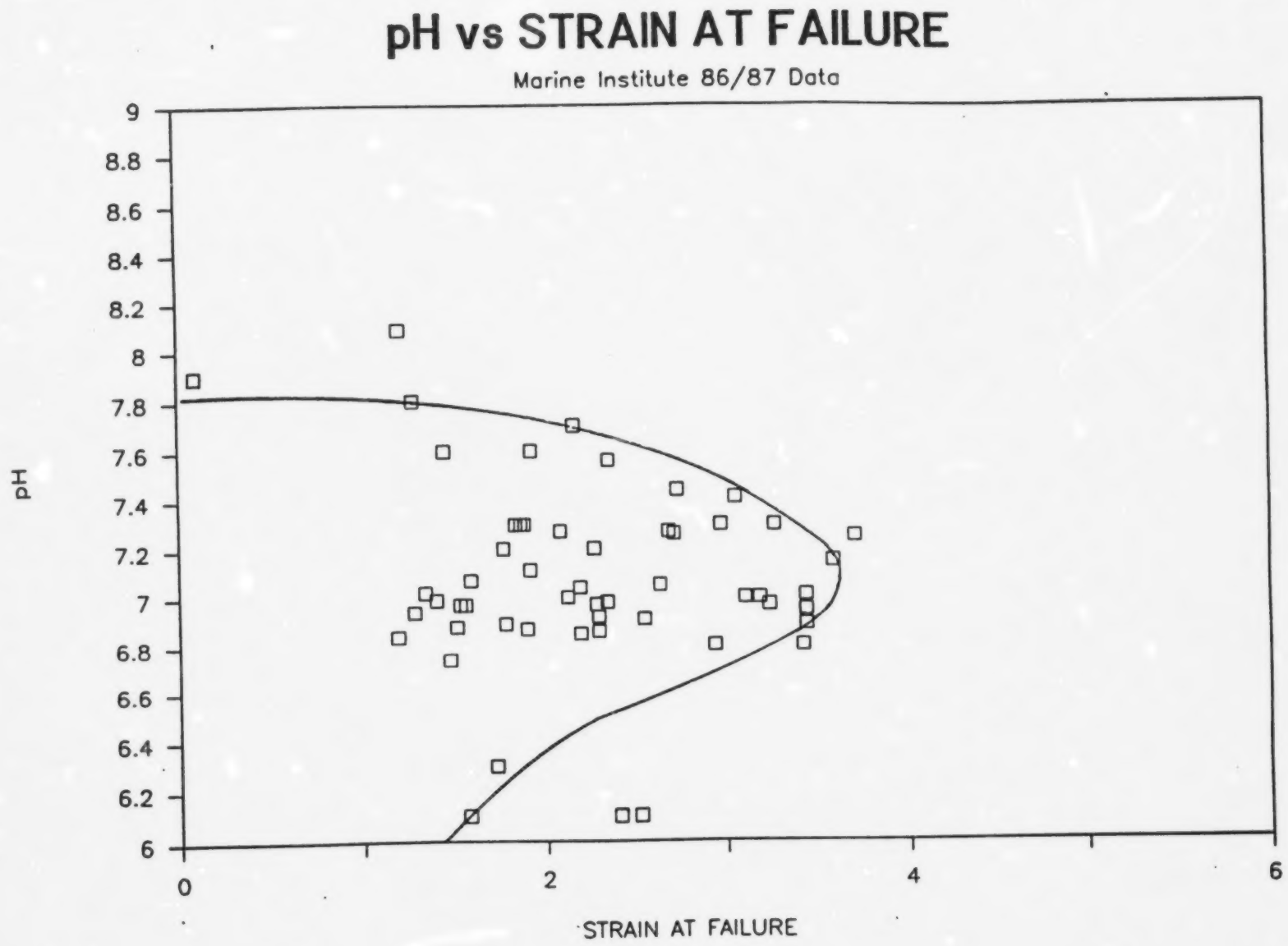


Figure 4.4 The strain value (elasticity) of cod surimi is greatest at about pH 7.4.

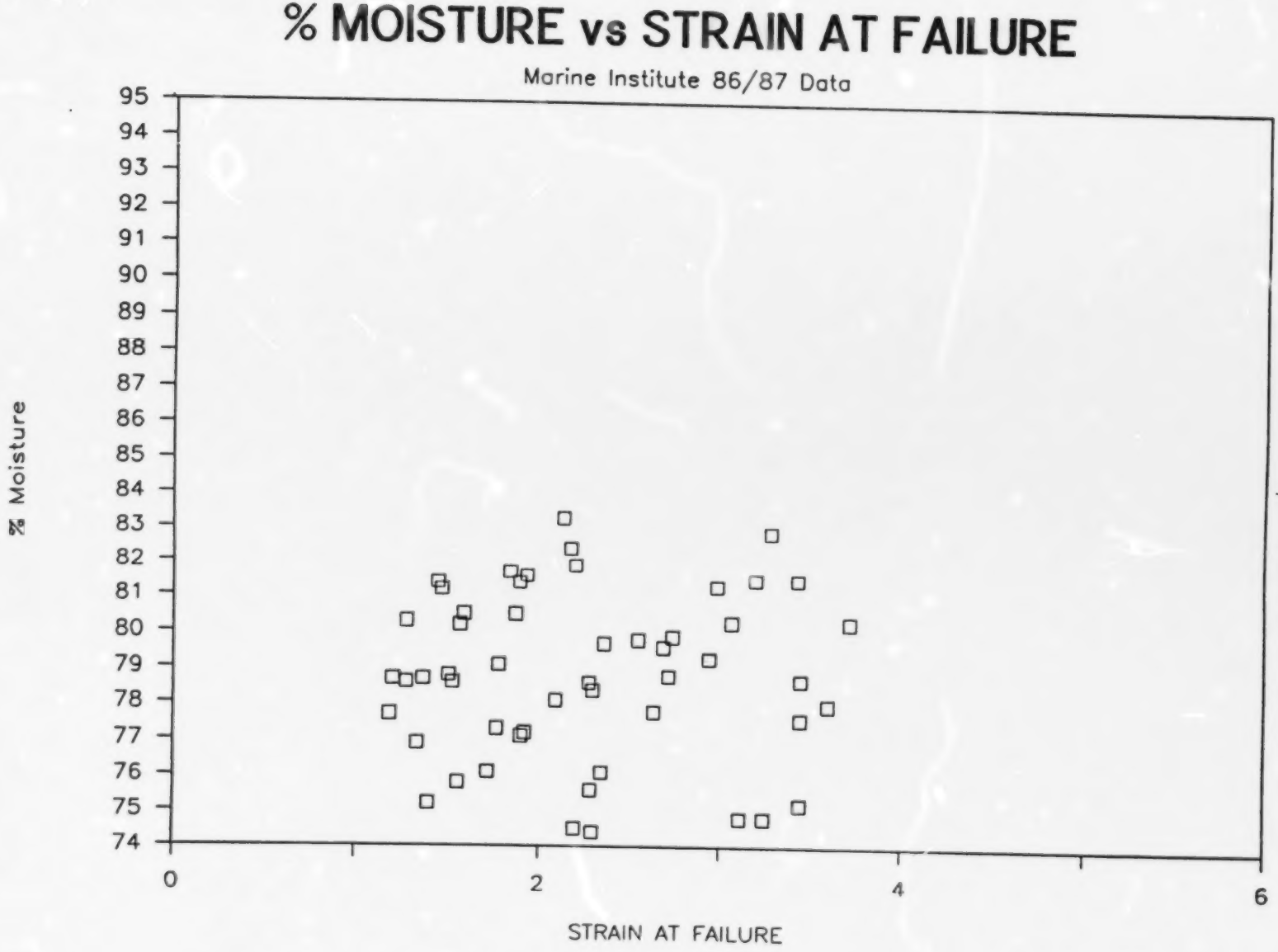


Figure 4.5 Moisture content has no discernable effect on the strain value (elasticity) of a gel.

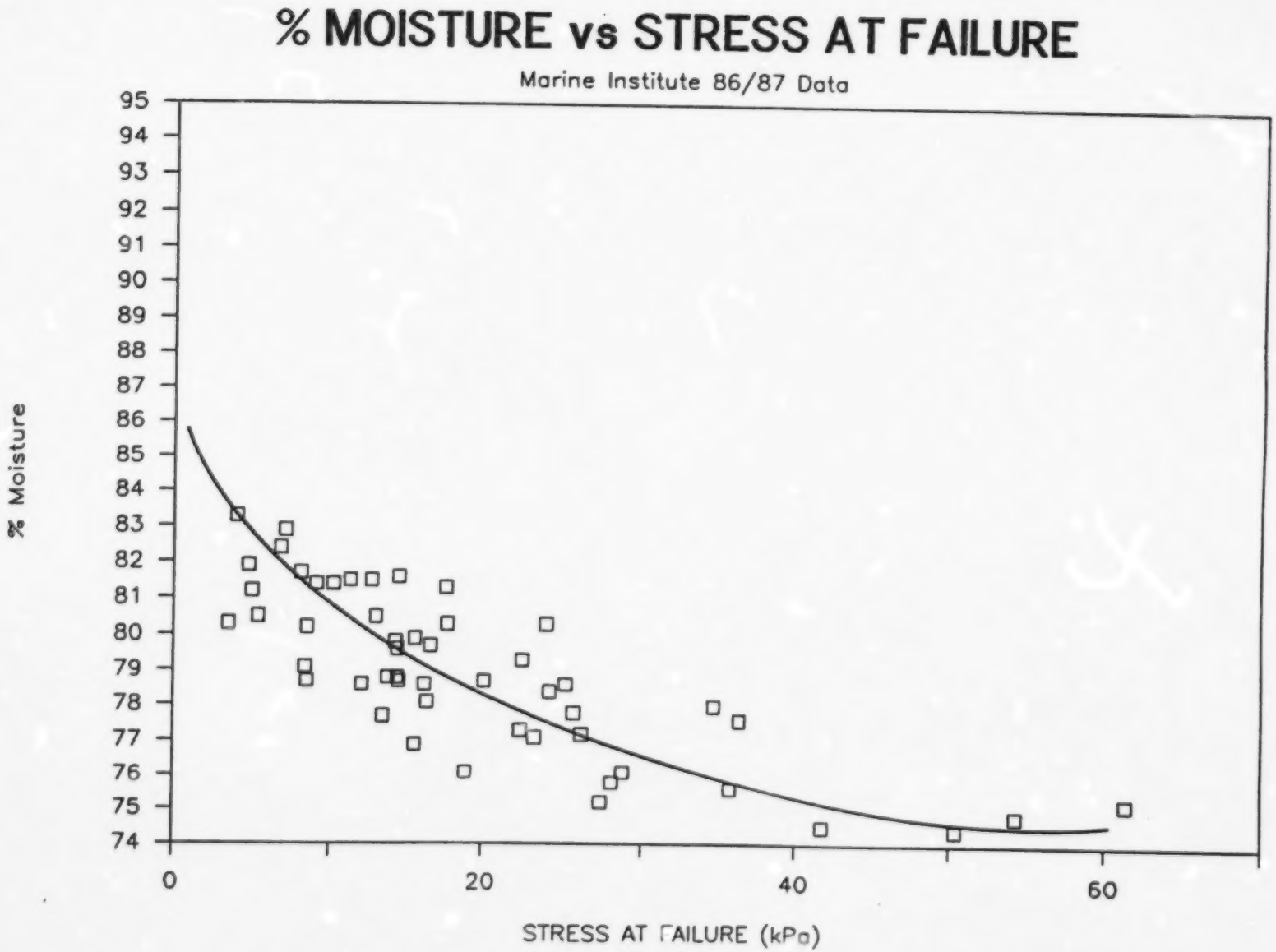


Figure 4.6 Moisture content is a primary factor in determining the stress value (rigidity) of a gel.

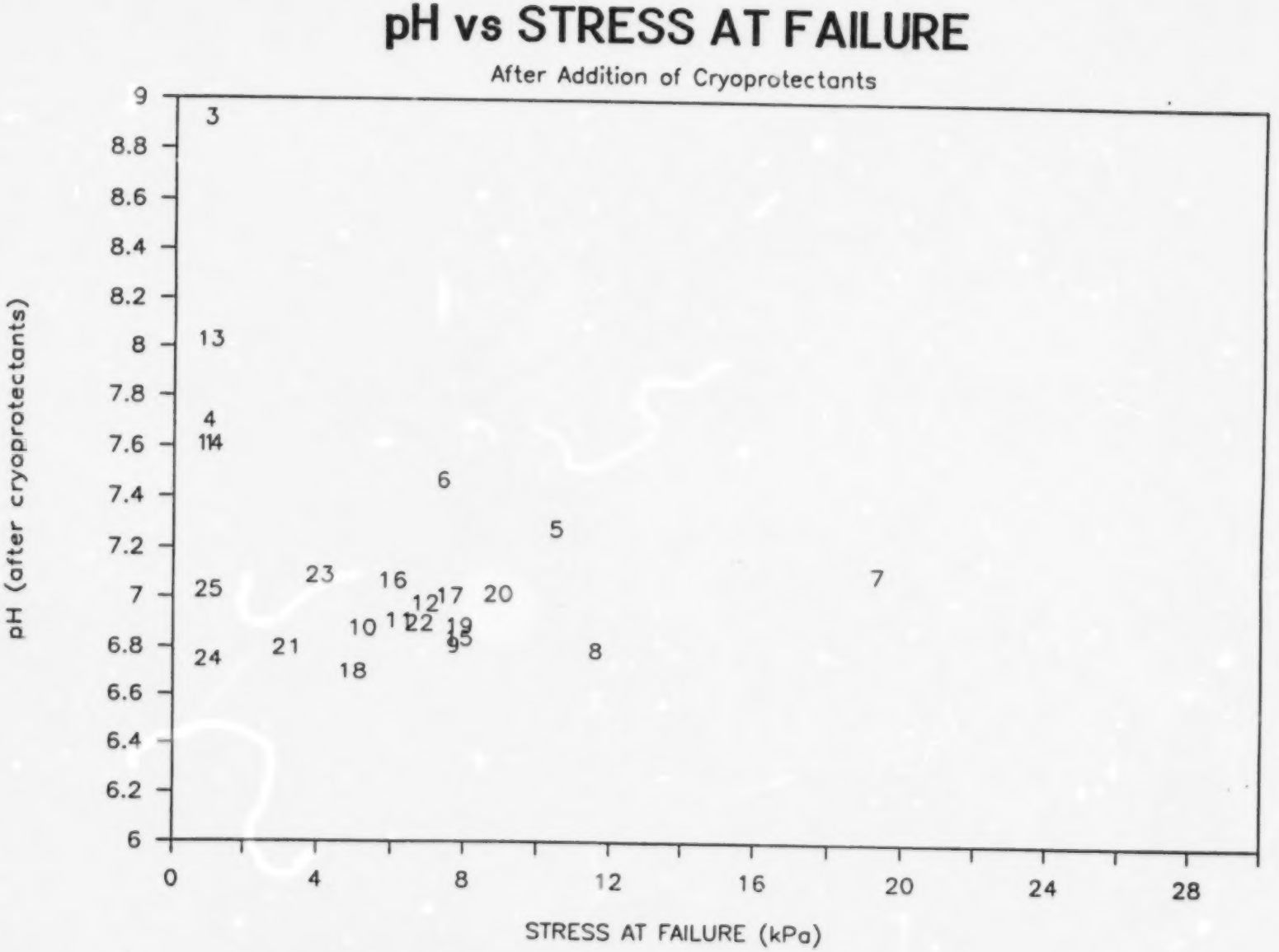


Figure 4.7 There is little correlation between the pH and the stress value (rigidity) of a gel. Note that the data below stress value 5 was "zero gel strength" and should be ignored in interpreting trends.

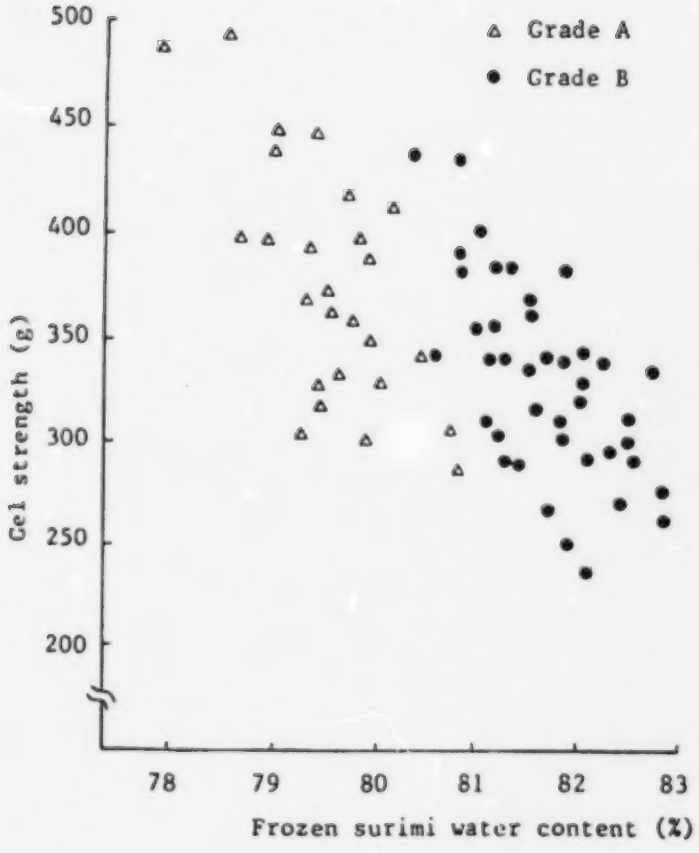


Figure 4.8 Water content and gel strength of frozen surimi. (Okada, M., 1986).

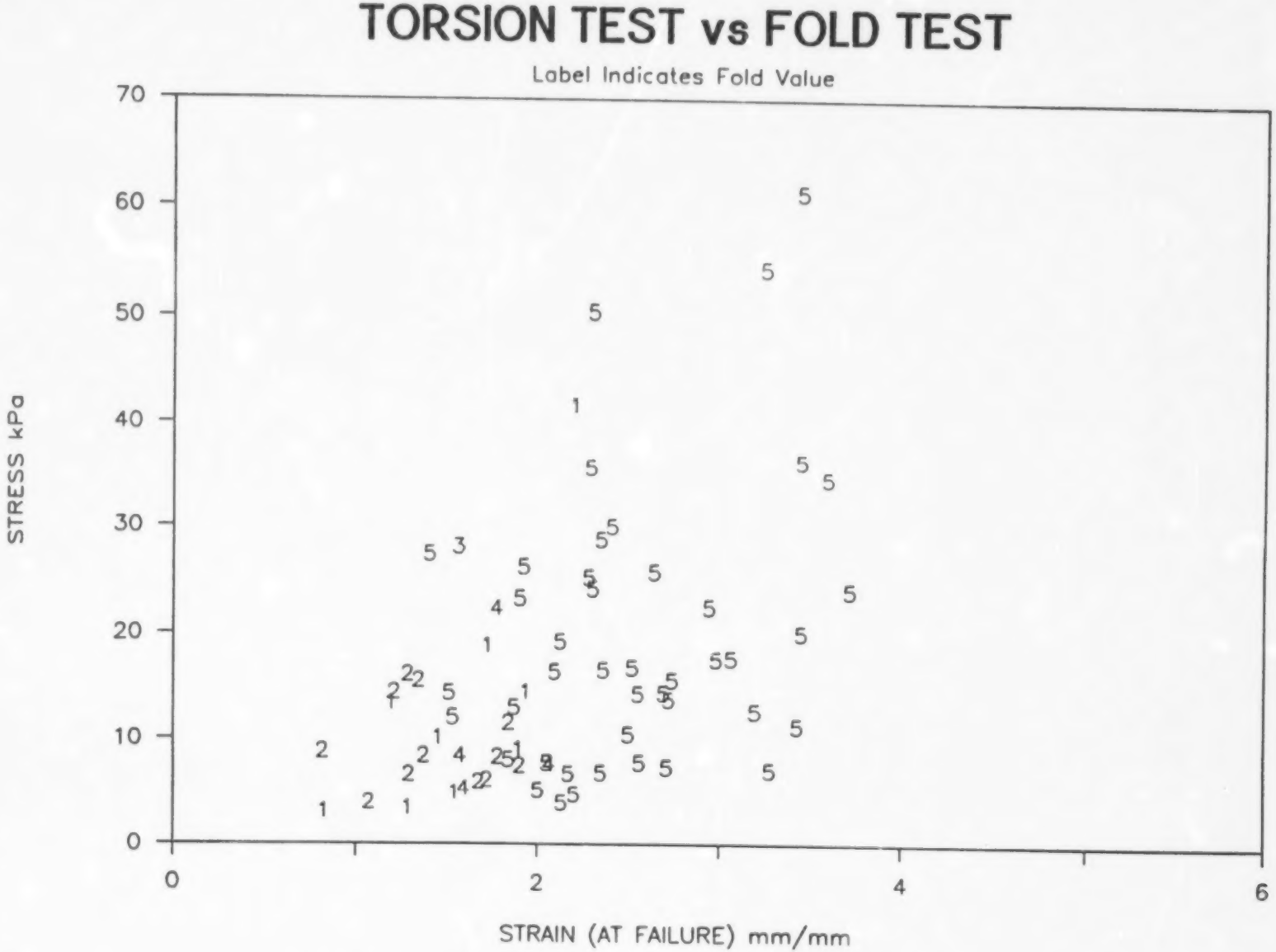
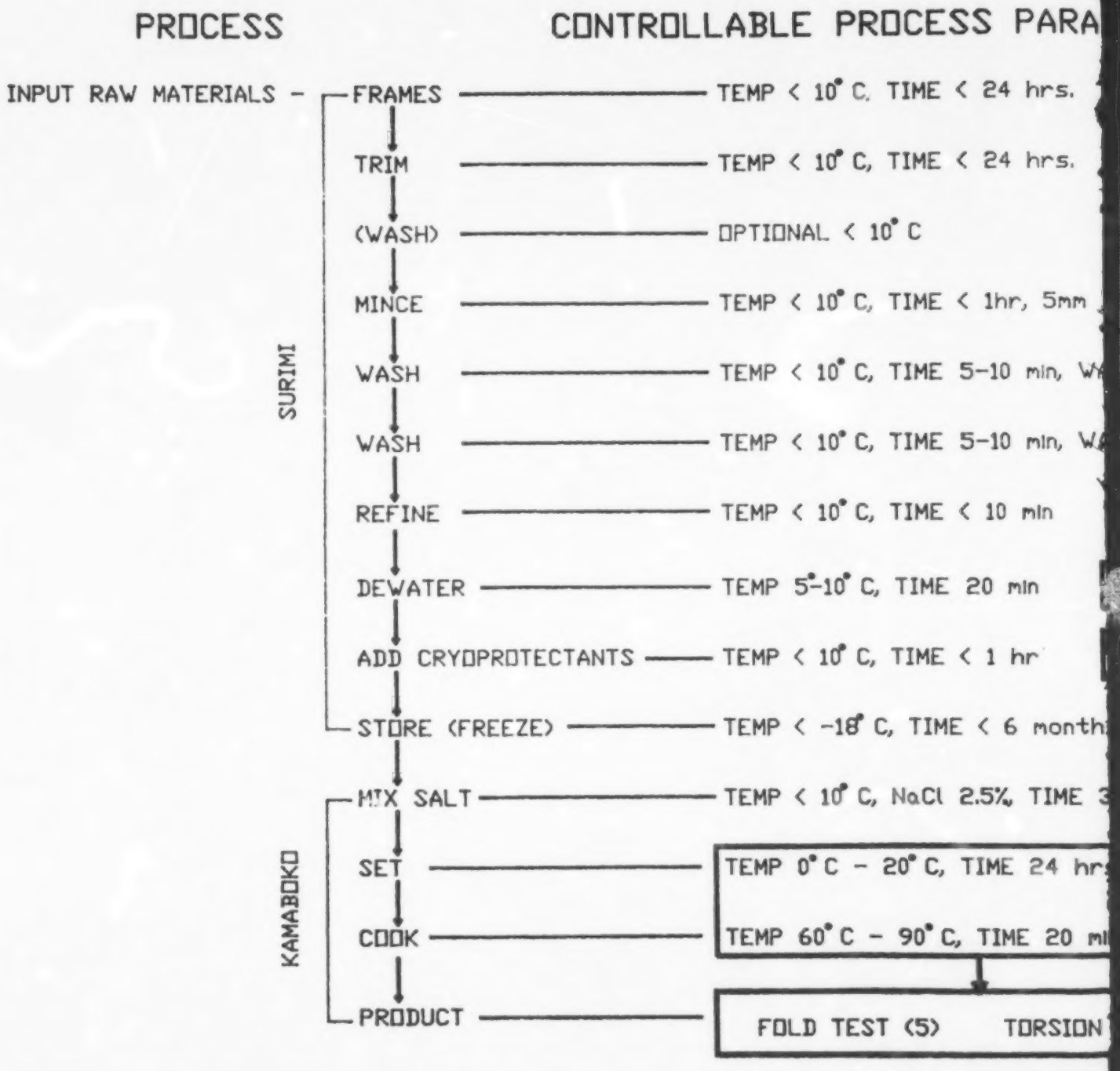


Figure 4.9 Plot of corresponding fold test and torsion test values for cod surimi. A strain value greater than 2.0 correlates with a fold test of 5 regardless of the stress value or rigidity of the gel (accumulated historical data)

FIGURE 4.10

SURIMI PROCESS



URE 4.10

ICESS ALGORITHM

S PARAMETERS DOMINANT CONTROL PARAMETERS

24 hrs.

24 hrs.

1hr, 5mm DEBONER

-10 min, WATER 3:1

-10 min, WATER 3:1

10 min

) min

1 hr

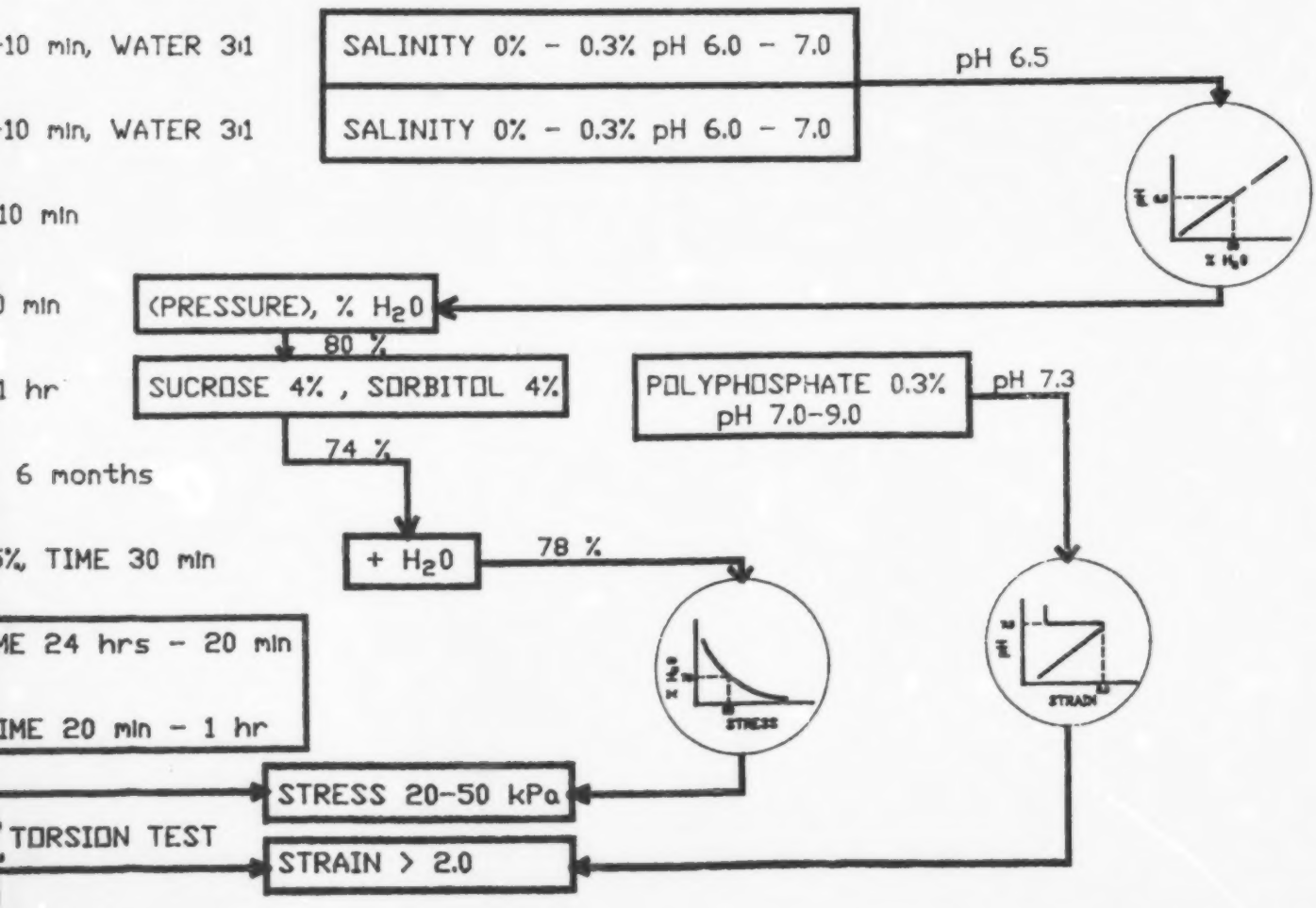
6 months

%, TIME 30 min

ME 24 hrs - 20 min

IME 20 min - 1 hr

TORSION TEST



5.0 PROCESS CONTROL DESIGN

5.1 Design Criteria

The ensuing design for a surimi process controller has been developed as a system suitable for retrofit to an existing surimi production line equivalent to one of the production systems operating onshore in North America. The following design/performance guidelines have been used:

FUNCTION:

The system is to function as a "processing assistant" for the surimi line operator.

* The system will take care of routine chemical control functions such as pH, salinity and temperature following general instruction from the operator.
* The system will provide the operator with process status information (i.e., temperature, pressure, pH, time lapse, etc.).
* The system will provide the operator with prompts for processing procedures specific for the raw materials being used and based on an optimized processing recipe.
* The system will log processing conditions for later comparison with production and quality data in order to provide the production manager with a basis for optimizing operations.
* The system will not be configured for full automated control of the process line.

DESIGN:

* The system will consist of components selected for reliability of operation and for simple maintenance.
* The system will be fail safe in as far as component failure will not interfere with process line function or with manual operation.
* The system will provide operator prompts that are easily interpreted and that have built-in defaults to a "standard operating recipe. In other words the system will provide process information, will request input data but will carry on its processing control functions with minimal attention from the operator.
* The control system will be adaptive in order that the processor can develop a set of operating recipes (trade secret) for different products and raw materials.

5.2 The "OPERATING ASSISTANT"

The process control system ("OPERATING ASSISTANT") configuration is shown in Figure 5.1 Processing line sensors feed information to the "OPERATING ASSISTANT". The Assistant requests raw materials information from the operator and provides the operator with process condition information as well as with procedural recommendations for those functions under operator control. The recommendations to the operator are based on a process algorithm for the specific raw materials plus whatever "trade secret" process information the surimi manufacturer may enter into the "OPERATING ASSISTANT".

The "OPERATING ASSISTANT" will control such functions as are easily

automated (e.g. pH, salinity and temperature). The "OPERATING ASSISTANT" will also specify chemical formulations for the cryoprotectant additives since this formulation may vary according to process conditions.

The "OPERATING ASSISTANT" will store process information on an hourly basis. This data will be used by the production manager along with production information such as quality, color, throughput and market value to optimize the production process. The "OPERATING ASSISTANT" will provide the production manager with a simple menu driven input facility that can be used to modify, update or expand the recipe base that the "OPERATING ASSISTANT" relys on when determining the best operating conditions.

The latter function will enable a surimi processor to develop and optimize proprietary processing methods as derived from research and from production experience.

The basic recipe built into the "OPERATING ASSISTANT" is illustrated in Figure 4.10. The process algorithms indicated by the circled graphs, are appropriate to the production of surimi from cod frame materials. The default values for desired product quality have been set in terms of torsion test stress and strain values. These can be related to the fold test or other commercial quality indices.

The actual sensor/actuator/controller hardware is outlined in Figures 5.2, 5.3. (Note Figure 5.3 is shown in Appendix F). These hardware specifications are general and would have to be adapted for any specific processing hardware.

The hardware for the controller is functionally specified in figure 5.4. The attendant software would be based on relatively low speed logical processing. Adaptive program technologies such as expert systems are not

specified but could be used if a processor required automated adaptation to changing processing conditions.

The cost of the "OPERATING ASSISTANT" has been estimated at $150,000. A cost breakdown by component is shown in Table 5.1

TABLE 5.1
"OPERATING ASSISTANT" Full Cost Estimate
For a one-time custom preparation

ITEM	COMPONENT		COST	TOTAL
Sensors	12 Thermocouples	@ 100	$1,200	
	(2) pH	@ 250	500	
	(2) Salinity	@ 2,000	4,000	
	(3) Pressure	@ 750	2,250	
	(1) Moisture	@10,000	10,000	
	Mounting hardware, wiring, etc.		5,000	
	Assembly, installation & commissioning		15,000	37,950
Actuators	(2) Metering pumps	@ 1,000	2,000	
	(2) Tanks	@ 500	1,000	
	(2) Manifold Housing	@ 2,500	5,000	
	Misc Plumbing & hardware		5,000	
	Assembly installation & commissioning		5,000	18,000
Controller	(1) Computer		5,000	
	(1) Waterproof housing & keyboard		2,500	
	(1) Waterproof display		1,500	
	(1) Data I/O		2,500	
	(1) Electrical interface		2,500	
	(1) Data storage		2,500	
	Assembly, installation & commissioning		5,000	21,500
Software	(1) Sensor data acquisition		5,000	
	(1) Control algorithm		15,000	
	(3) Actuator output		5,000	
	(4) Operator Interface		15,000	
	(5) Data store		5,000	
	(6) Process Adaptation Interface		15,000	60,000
Commissioning			15,000	15,000
				152,450

Figure 5.1

HYBRID SURIMI PROCESS CONTROL

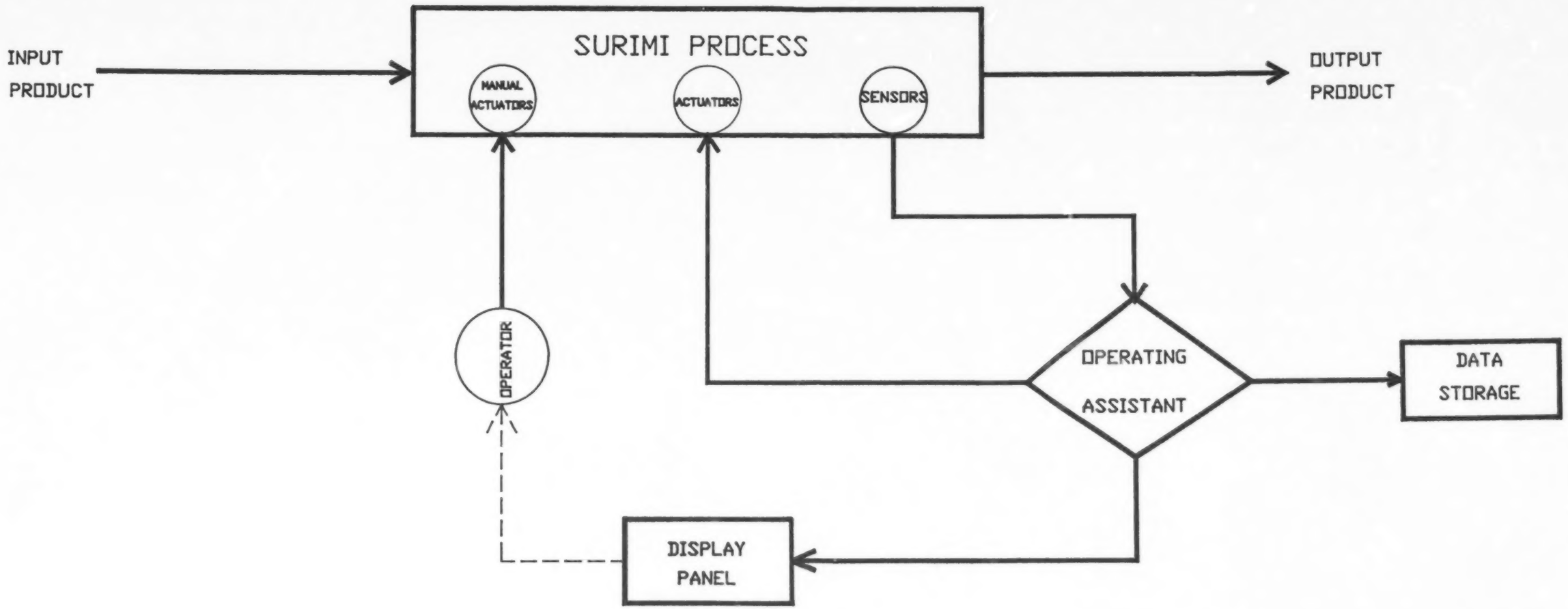
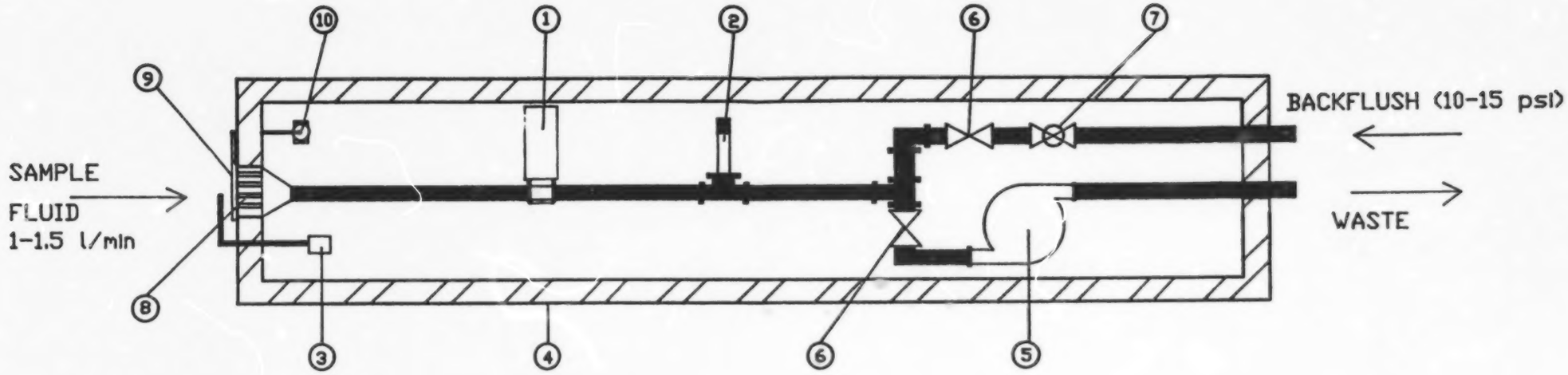


FIGURE 5.2

SENSOR MANIFOLD



SENSORS/MATERIALS

① AANDERAA INSTRUMENTS Salinity Sensor 2975
② EXTECH INSTRUMENTS self cleaning, gel filled pH electrode
③ OMEGA ENGINEERING J type thermocouple
④ Stainless steel pipe section
⑤ Pump, positive displacment, self cleaning
⑥ Solenoid Control Valve
⑦ Pressure Regulator
⑧ Perforated stainless steel
⑨ Wiper
⑩ Wiper drive

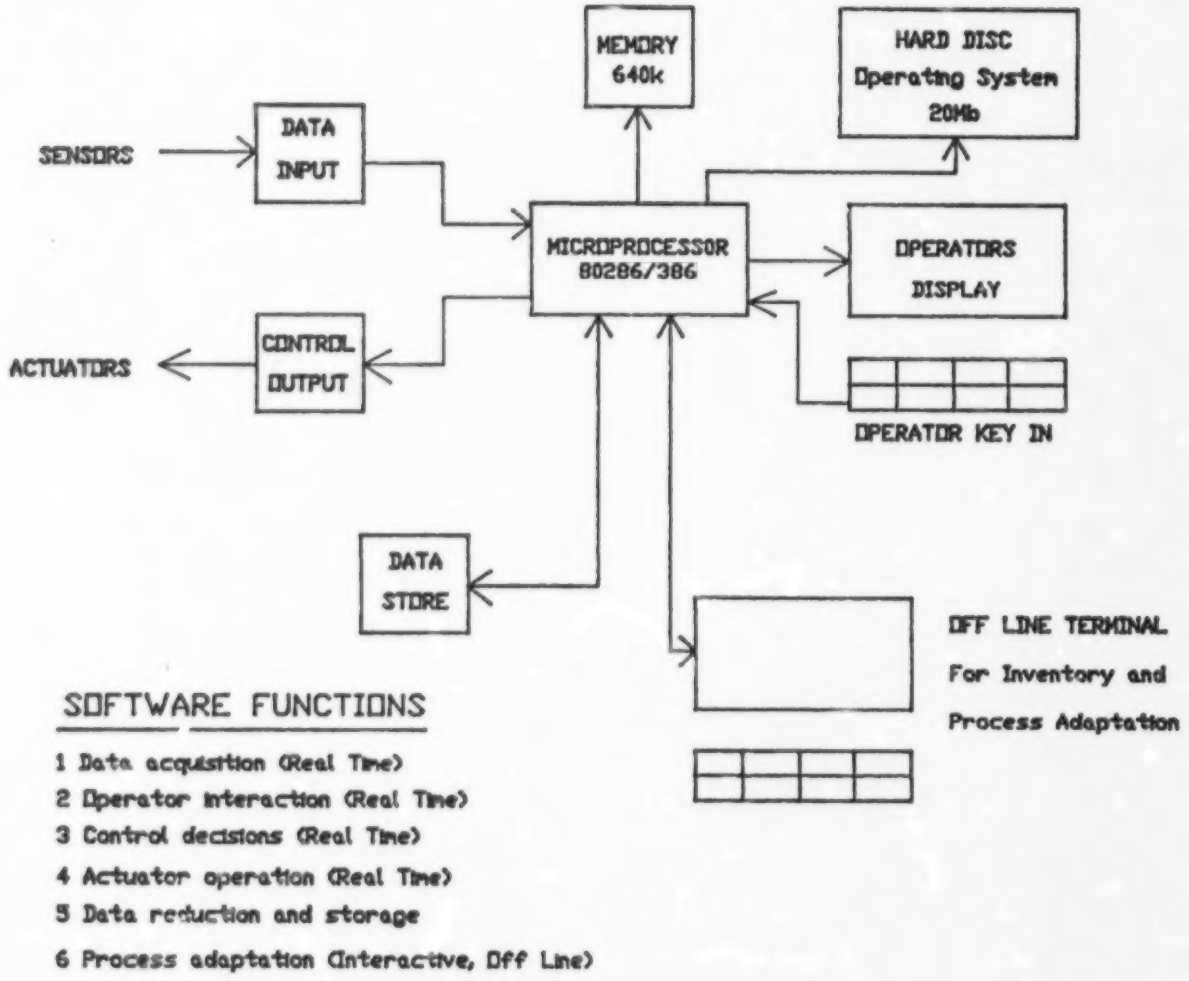


Figure 5.4 Controller hardware and software block diagram

ACKNOWLEDGEMENTS

We would like to acknowledge the collaboration of the Marine Institute in this project. Messrs. B. Gillet, Kirk Loveys and C. Chandra carried out all of the experimental surimi processing and laboratory evaluation work.

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Canpolar staff involved in this project include Paul Hearn, Craig Taylor, Mike Hawco* and Ernie Reimer.

* Currently with Fishery Products International.

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